W. B. No. 959

UNITED STATES DEPARTMENT OF AGRICULTURE
WEATHER BUREAU

VOLUME 56 NUMBER 6

# MONTHLY WEATHER REVIEW

## JUNE, 1928

CONTENTS



UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON
1928

# MONTHLY WEATHER REVIEW

Editor, ALFRED J. HENRY

VOL. 56, No. 6
W. B. No. 959

JUNE, 1928

CLOSED AUGUST 3, 1928
ISSUED AUGUST 31, 1928

## WATERSPOUTS

By WILLIS EDWIN HURD

[Weather Bureau, Washington, June 25, 1928]

In an article prepared especially for seamen and shortly to be published on one or more of the monthly Pilot Charts of the United States Hydrographic Office (1), the writer has discussed the subject of the waterspout at some length. There the reports of marine observers are quoted freely to illustrate not only the individual behavior of numerous spouts, but also the varying conditions under which they occur. References of this character are omitted from the present paper, which is a summary of the more important facts only.

While waterspouts closely resemble true tornadoes in most phases of outward appearance, and both have many other features in common, yet in method of origin, and in some individual characteristics, they are often distinctly different.

The true tornado, as Doctor Humphreys points out (2), is a "joint product of cyclone and anticyclone," and occurs just in advance of the squall line which marks the change from the equatorial winds of the low-pressure region to the polar winds that succeed them. This characteristic, together with its probably invariable contraclockwise wind circulation in the Northern Hemisphere, must be considered as wholly typical of the disturbance.

The sand pillar of the Central and Southwestern States is frequently called a tornado. But since its origin is entirely convectional, the whirl rising from the heated surface and rotating either to right or left, while the tornado forms at or near the cloud level, the whirl thence being communicated earthward in what we see as a left-handed rotation, it becomes apparent that the two have well-marked points of dissimilarity.

Now the waterspout partakes in great measure of the nature and behavior of the tornado, or of the sand pillar, as the case may be, probably obeying the impulse to complete a contraclockwise whirl downward from the cloud, in the one instance, or tending to obey the convectional impulse to rise in one way of whirl or the other, in the second. Whence we may properly style them as tornado spouts and convection spouts. Sometimes the spout will be formed by a combination of conditions, in which case the rotation will be clockwise or counterclockwise, according to the local conditions prevailing at the place and moment of the inception of the eddy. Only about 1 in 15 of all waterspout observations—whether made by seamen or by land observers—mentions the direction of rotation, but from these comparative few it is shown that slightly more than half are of the tornadic, or left-handed, type.

*Waterspouts that go ashore.*—Many waterspouts on touching land are almost immediately dissipated, the base breaking up and the upper part of the funnel withdrawing into the cloud. Others—doubtless strongly of the tornado type—give up much of their liquid content as they go ashore, and, gaining new rotational energy, may become dangerous land tornadoes. Similarly, tornadoes, upon passing over a water surface of moment and perhaps taking up liquid, may change their name, though not their characteristics, and become known as waterspouts. An interesting example of a spout going ashore is found in the violent local storm known as the Goulds tornado, which did much damage southwest of Miami, Fla., September 10, 1919, during the prevalence of the West Indian hurricane of the 6th–14th. This originated as a waterspout, so called, over the near-by ocean or in Biscayne Bay.

*Localities of occurrence.*—While the waterspout is often considered to be a phenomenon only of the salt-water bodies of the world, yet it is not so confined in its activities, since true vortices of this type occasionally make their appearance on the lakes and rivers of many lands. Numerous instances are given of those of the mountain lakes and of the larger quiet streams of Europe. They are found occurring in the United States, more especially on Lake Erie, and reports of them sift in now and then from African, Asiatic, and other continental localities.

On the North Atlantic Ocean, including its contiguous gulfs, bays, and seas, waterspouts have been observed from the Baltic to the Gulf of St. Lawrence; from the eastern end of the Mediterranean to the farthest Caribbean and the Gulf of Mexico, and in fact over almost all the ocean, though they are rather uncommon in the most settled regions of the northeast trades, where the general regularity of the weather conditions is not favorable to their formation. The principal region of activity is embraced between the tropical African coast and the Central American and Mexican coasts, with an extension northward from the West Indies to the upper limit of the Gulf Stream. In this considerable area a band of maximum activity extends from the Gulf of Mexico through the Florida Strait past the Bahamas and up the coastal waters to, and to the eastward of, Cape Cod.

In the North Pacific Ocean the region of maximum waterspout activity lies off the Mexican and Central American coasts, within a great triangular region of prevailing variable winds and calms. Extending northward from it is a band of occasional occurrence which conforms closely in area to the long fog bank stretching from Cape San Lucas to Puget Sound. Thence westward to the Kuro Siwo waterspouts are reported very infrequently. At Honolulu the only occurrences of record are three

spouts that formed in the harbor on January 1, 1927. A secondary area of considerable activity embraces the China and other seas adjacent to the Asiatic coast.

In the Indian and South Pacific Oceans waterspouts form most frequently in East Indian and Australian waters and about the various archipelagoes both far and near to the eastward.

For the South Atlantic Ocean little information is available, although ships' reports make occasional mention of spouts in many localities.

*Monthly and seasonal occurrence.*—While waterspouts are likely to occur at any time of the year in waters appreciably subject to them, yet a more or less pronounced average seasonal shift with latitude is observed in the Northern Hemisphere, the greater number forming in the Tropics during the fall and winter months, and in the Temperate Zone during the late spring, late summer, and early fall months. For the tropical waters of the Atlantic, between latitudes 10° S. and 20° N., Hellmann (**3**) found that three-fourths of the waterspouts studied by him from the ships' reports of 26 years in these latitudes occurred from October to March. Gibson, in a special study (**4**) based upon waterspout data appearing on the United States Pilot Charts of the Hydrographic Office from January, 1884, to March, 1886, inclusive, found that out of 245 spouts observed along the American coast from Panama to Cape Cod, 70 per cent occurred during the summer half of the year, with the greatest monthly occurrence, 14½ per cent, in May. The least number for the year was credited to November.

In the present writer's more general treatment, about 65 per cent of waterspouts plotted for the entire North Atlantic were for the warmer months, May to October, inclusive. The months of maximum frequency for the year were found to be April, May, August, September, and October, with the greatest number occurring in August. The months of minimum occurrence were shown to be March, July, November, and December. That the adjoining months of July and August should present the minimum and maximum extremes of frequency is of peculiar interest. While no figures of spout frequency, owing to scantiness or incompleteness of data for the periods covered, are sufficient to make for desirable accuracy, yet they do point out reasonably well the times of rise and fall in waterspout production on the North Atlantic Ocean. Off the coast of Florida the greatest number for any month seems to occur in May, and to the northward, in August. In connection with the occurrence of spouts in winter, it is interesting to note that the North Atlantic Pilot Chart for March, 1888, describes about 40 that were reported between Cuba and the Grand Banks during the preceding January and February.

In a study covering the period from December 17, 1888, to June 30, 1898, Russell (**5**) mentions 38 waterspouts observed off Eden, on the coast of New South Wales. These were fairly well distributed according to seasons, with March the month of greatest frequency. Of the entire number, over half, or 20, made their appearance during a period of five hours on May 16, 1898.

*American fresh-water spouts.*—During the search for data bearing upon the general subject of waterspouts, records were discovered of some 36 vortices of this type occurring in the inland waters of, or waters contiguous to, the United States. Of this number 20 were observed on Lake Erie, 4 on Lake Ontario, 1 on Lake Michigan, 1 on Lake Newcomb, N. Y., 2 on Lake Monroe, Fla., 2 on the St. Johns River, Fla., 2 on the Mississippi River, 2 on the Chester River, Md., and 1 each on the Potomac and St. Lawrence Rivers. Seven of these were observed upon one occasion on Lake Erie, August 13, 1898, between 7.30 and 9 a. m. All but three occurred during the months, May to September, with the majority in August. One of the three formed February 11, 1907, during very cold weather, over a small stretch of open water at the eastern end of Lake Erie. Another formed in the St. Johns River, near Jacksonville, on April 18, 1888, and the third appeared in the Potomac River, at Washington, D. C., November 17, 1927. The spouts enumerated are doubtless scarcely more than casual findings, and the subject is worthy of a careful study. Such information regarding them as appeared in the reports indicates that fresh-water spouts rotate in either sense, as do their neighbors of the salt water and the sand whirls of the desert.

*Hour of occurrence.*—Whenever the meteorological conditions are favorable, waterspouts may occur, whatever the time of day. Such conditions usually exist only during the daylight hours, but on several occasions the phenomenon has taken place during the hours of darkness, both before and after midnight. In the Tropics of the Atlantic, Hellmann (**3**) records 34 spouts in which the hour of occurrence was given by the observers. Of these, 21 formed before and 13 after noon, with times of most frequent appearance between 6 and 7 a. m. and near noon. The present study of hundreds of spouts observed for the Atlantic as a whole shows that they are most frequent during the early forenoon, late afternoon, and midday hours, but with only slight intermediate lessenings. There seems to be little difference in the numbers formed during the a. m. and p. m. hours.

*Weather conditions under which waterspouts occur.*—A much wider range of weather conditions favorable to waterspout formation exists at sea than is equally favorable to the production of all combined types of local whirls on land. The waterspout originates not only along or near the squall line separating cyclones from anticyclones, or over quiet and considerably heated tropical sea areas, but it occurs at almost any point within distinctive high or low pressure regions; also wherever fairly well-developed squalls occur along discontinuity surfaces, though unmarked by barometric changes of moment, either in the doldrums, or wherever the atmosphere exists in a state of unstable equilibrium. Spouts also occur, and quite frequently, in connection with ordinary thunderstorms.

While waterspouts are usually associated, at least in popular conception, with warm, sultry weather, yet they are by no means uncommon during the prevalence of low air temperatures, especially if over a warm-water surface. Gibson (**4**) found that out of 51 cold-weather spouts definitely assigned to low-pressure areas, 36 formed in the southwest quadrants and 15 in the southeast. Of 46 warm-weather spouts, the condition was reversed, 18 occurring in the southwest quadrants and 28 in the southeast. Winter spouts during the three years under study were most abundant when low temperatures prevailed and winds were from a north to west direction, and summer spouts, when the winds were south to east. As an example of the former: On February 21, 1886, 10 waterspouts formed in and near the Gulf Stream, following the passage of a cyclone center, during the prevalence of squally and violent winds which sometimes attained to hurricane force from the north-northwest. Less frequently spouts occur in winter over portions of the sea quite remote from a warm current, when temperatures of both air and water are below 50°, with atmos-

pheric conditions tending toward the production of local squalls, though with no marked cyclonic weather necessarily prevailing.

Unless formation occurs under changing cyclonic or anticyclonic conditions, the weather preceding, during, and following a waterspout exhibits little change, temperature, pressure, wind, and humidity usually remaining practically undisturbed. In close proximity to the whirl, however, there is often accelerated wind, and sometimes, though not always, slight barometric fluctuations, pressure disturbances being ordinarily confined to the spout proper.

*Windspouts and waterspouts: Water content.*—While a majority of all fully developed sea spouts carry a greater or less quantity of water in suspension, yet many are mere wind whirls of convectional origin which contain no more water vapor than would be found in a bank of dry to ordinary fog. The latter are usually of no great violence, perhaps no greater than the dust whirls which they resemble, although capable of doing some damage to a small vessel. They occur for the most part during quiet weather over areas of considerably heated water. While sometimes little disturbing to the surface over which they travel, more often they throw up a small cloud of spray—the usual cascade—for a few feet into the air.

True waterspouts contain, in addition to condensed water, an uncertain quantity of sea water drawn to a height which depends upon the intensity of the disturbance, and therefore the lifting power of the rising winds. Thus, under extreme circumstances, the quantity of surcharged vapor and free water is so great as to produce the equivalent of a cloud-burst, upon its discharge. This water has often been spoken of by seamen upon vessels struck by waterspouts as being wholly fresh, but by others as having a saline taste. A few reports are current of salt water having been carried in such quantities up the spout to the clouds as to be noticeable in the precipitation occurring at a distance. This was true of the Cottage City (Oak Bluffs) waterspout of August 19, 1896, some time following the disappearance of which, saline rains fell over Marthas Vineyard Island (6). Since this spout, the history of which was given much publicity, was estimated to have been at least 3,600 feet high, the vertical distance to which the sea water was raised is seen to have been considerable.

*Simultaneous numbers.*—While often only a single waterspout forms in a given instance, yet 2 to 10 quite frequently occur together, and 15 to 20 occasionally have been witnessed off the south and east coasts of the United States, and in mid-Atlantic. Groups of spouts in as great numbers have also been observed in various localities in other oceans.

*Waterspout-bearing clouds.*—In general the most vigorous spouts are associated with the heavy cloud masses of the cumulo-nimbus type and the almost equally dense nimbus of energetic cyclones. Less vigorous spouts as a rule form in connection with cumulus, strato-cumulus, and stratus clouds. Spouts occur most frequently in connection with cumulo-nimbus clouds, and least frequently with strato-cumulus. Group spouts in bunches or irregular formation are found most often in squall clouds, whether these accompany violent upper air changes in cyclones, or fair weather convective turbulence. Group spouts in line formation may sometimes be found in rows of long cumulus clouds, or in single strato-cumulus bands, and are most likely to occur in the tropics in such localities as, for instance, in the neighborhood of the Bahamas, or off the west coast of Mexico, during fair weather. Frequently many of these are immature, ranging from mere protuberances at the base of the cloud to half-formed pendants.

Occasionally low spouts are seen traveling along as mere tubes with no accompanying clouds. Other spouts, whether low or moderately high, sometimes induce the formation of a cloud summit in the over-flowing vapor, as a result of convection and vortical action.

*Lightning.*—Electrical phenomena occur in general with waterspouts only when the atmospheric conditions are such as to be favorable for thunderstorms.

*Precipitation.*—Rain is not invariable. When it does fall it may be extremely light to excessive. Upon the sudden disintegration of a spout, water sometimes falls as a cloudburst. In cold weather snow occasionally accompanies a spout cloud. Hail occurs as in thunderstorms, when convection is violent, and sometimes there is a fall of large and irregular ice chunks.

*Sounds.*—Faint and uncertain murmurings are sometimes heard prior to the completion of a spout, but when full development is reached, the sounds swell into roarings, grindings, and hissings, the volume depending upon the intensity of the disturbance.

*Wind violence.*—This is far less on the average than in the tornado, although the force exerted in the waterspout has not been determined as exactly as that in the land storm. Small vessels that have passed through spouts have often received only local damage, though sometimes there has been an overturning or a complete wrecking of the craft. Often the mischief wrought is as much due to the deluge of water as to the force and twist of the wind. The roarings which accompany a waterspout are occasionally sufficiently loud and terrific to indicate that the wind is rotating with great violence. Vessels, however large, do not take chances voluntarily with even the least formidable of these whirls.

*Translatory speed.*—Many spouts are practically stationary throughout their brief careers. Others are reported as traveling at a high rate of speed, estimated at from 50 to even 80 miles an hour. In the majority of instances the rate is in excess of 15 or 20 miles. The Cottage City waterspout had a speed of close to a mile an hour, as could be accurately determined, it being near land and under close observation with reference to known positions. The speed sometimes varies even among the members of a group, and regardless of the force of the surface wind, thus indicating differences in velocity of the adjacent air currents at the elevation in which formation occurs. It is observed that rapid forward movement sometimes occurs even though the surface air be calm.

*Progression and verticality as related to wind direction.*—The spout usually moves with, or nearly with, the current in which it has origin, the convection-formed type going with the surface wind, and the squall-formed variety with the upper current in which it becomes engaged. Therefore, the direction may be at any angle with or against the surface wind, whatever its force. When the wind is light, though variable, or steady and of the same direction from cloud to surface, the spout usually maintains a perpendicular position. Differences in wind velocity result in a backward or forward bending, which may be straight or curved. When the wind surfaces are strong and conflicting, the spout becomes variously contorted, or it may even be torn asunder at the weakest point, which is somewhere midway of the stem.

*Length of path.*—Owing to lack of continued observation points, the length of the path can not be determined for any waterspout the beginning or ending of which is beyond the range of an individual vision. Many spouts break up almost at the spot of formation, and since the

average spout lasts for only a few minutes, it can proceed for only a few miles at the utmost. The average length is apparently far less than that of the tornado.

*Life period.*—Very few individual spouts are known to have existed for more than an hour or so. Usually they last less than half that time, and the average length of existence is probably not far from 15 or 20 minutes. In the present study, largely based upon original data, the life period has ranged from three minutes to slightly over an hour, with neither the time of beginning nor ending of the longest observed one known. Favorable conditions for spout formation sometimes last for several hours, many individuals forming and dissipating within eye distance during the period.

*Size.*—While the average size of waterspouts is not so great as that of land tornadoes, individual spouts sometimes attain to considerable dimensions. Some have been measured with precision from both land and shipboard points of vantage. Professor Bigelow (7) computed the following measurements for the Cottage City waterspout of August 19, 1896:

| | Feet |
|---|---|
| Approximate length of tube | 3,600 |
| Diameter of tube at base of cloud | 840 |
| Diameter of tube at middle | 144 |
| Diameter of tube at water surface | 240 |
| Diameter of base of cascade | 720 |
| Height of cascade | 420 |

Measurements of a spout in Mobile Bay, June 12, 1925, indicated that it was approximately 2,600 feet high and 26 feet in diameter throughout its length. The cascade was some 10 feet high and 60 feet in diameter. The highest spout of which the writer has found accurate mention occurred off New South Wales, May 16, 1898 (5). By eye measurement on shipboard it was estimated to be 5,000 feet high. Theodolite measurements from shore confirmed this estimate and gave it a height of 5,014 feet. Some 4,500 feet of the tube was estimated to have a practically uniform width of 10 feet, greater widths occurring only along about 250 feet each of base and summit. Short spouts 200 feet and less in length are fairly frequent, but the most common lengths will approximate perhaps 1,000 to 2,000 feet. Some of the shorter ones are remarkably thick. One observed near Blunts Reef Light Vessel, California, November 14, 1914, was estimated to be 100 feet high and 700 feet thick. The longer ones are usually very narrow in comparison with their lengths, as in the instance of that off New South Wales. A spout seen off Rabat, Morocco, December 18, 1917, was said to have been 1,050 feet high and only 3 feet in diameter.

The principal size-determining factors are height of cloud, method of formation, whether at the surface or above it, and atmospheric humidity. With low clouds, or strong convection with or without clouds, and high relative humidity, the shorter and thicker as a rule will be the spouts. With more elevated clouds, high windshift surfaces, and lower humidity, the loftier and slenderer will they be. In connection with the humidity, it must be understood that a moderately high vapor content, at least, is generally necessary to spout production.

*Condensation along the spout line.*—Waterspouts that are formed by purely convectional processes sometimes, though not always, first materialize in visible form at the water surface. Often at the beginning the swirl development does not intensify sufficiently, or the dew-point temperature is not first arrived at, except at the level of the cloud which it sometimes induces, to cause much condensation. Whence, except for certain circular stirrings of the sea at the base of the whirl, the first visible intimation of its presence is the feeble downward projection at the cloud base. As the wind velocity in the upper part of the whirl increases, the condensation level progressively lowers and elongation of the visible line occurs. Usually before it has reached halfway to the surface, the lower end of the whirl similarly becomes visible through condensation, and the two projections then approach each other, meeting at the point where humidity is lowest, or the attaining of dew-point temperature is most retarded. Should the first cloudy cone rise from the sea, a similar appendage sooner or later drops to meet it from above, unless the column be extremely short. Sometimes, indeed, no visible spout forms, although there is an increase of wind to some little elevation, and all that is seen is a water whirligig which rises no more perhaps than a half dozen feet or less above the surface.

In the case of a spout originating at an elevated squall front most, if not all, of the column will invariably condense progressively downward, and only when the tip is near the surface will the cone from below sometimes rise to meet it. Thus there is frequently very little difference in the method by which condensation progresses, whether the wind-whirl originates at the surface or at the cloud level.

*Waterspout shapes.*—Like a pipestem, or a "huge circular tower," to quote from an observer, and of the same diameter throughout. These and similar descriptions apply to many. Others gradually narrow with descent until they come to comparatively little more than points at the surface. In some, but apparently in fewer instances, the reverse is true. Occasionally one bulges midway along the tube, seemingly breathing and throwing off vapor and water as it advances, though more frequently the diameter is least at some intermediate point, the narrowest portion occurring at the air layer where moisture content is least. Sometimes the width at both base and summit is much greater than along any other part of the tube, thus developing what is often spoken of as an hour-glass formation. Occasionally fantastic shapes and coils are observed, and if the latter occur, any contact of one part of the coil with another results in quick destruction to the whole.

*Double-walled spouts.*—There is no reason to assume that the usual waterspout has other than a single-walled tube, but that there are some with double walls is beyond question. An instance was reported by Dr. G. D. Hale Carpenter, of the Uganda Medical Service, as occurring on Lake Victoria (8). This waterspout was within 100 yards of the observer on shore, and the central core could be plainly seen, surrounded by a sheath, with a clear space separating the two walls. Several similar instances have been observed at sea. In one case on record, "after about 15 minutes the inner spout suddenly drew upward," while the outer one moved away and disappeared.

*Currents in and about the core.*—It is generally understood that the air rises spirally along the tube of the waterspout, although in many instances the circulation is invisible to the eye. The appearance of descending water, often noticed, probably is due to or results from the aqueous matter returning to the sea after being thrown out along the lower reach of the spout. Within the core itself ascending water has been reported on many occasions in instances where the envelope was more or less transparent, and descending air currents have likewise been reported. Franklin (9) makes reference to a

calm-weather spout, the base of which came to within 8 feet of the sea surface. From its circular orifice issued a violent stream of wind, to quote, "which made a hollow of about 6 feet diameter in the surface of the water." Doctor Fassig **(10)** mentions the instance of a vessel which collided with and went through the center of a waterspout. During the passage several objects on deck were drawn upward, among them the captain's log, which went vertically into the air for 40 feet, or the entire length of the attached line.

*The mound, or depression.*—Within the base of the spout a mound of water has often been reported as observed rising to a height of two or more feet. This can be conceived of as caused by a forcing up of the sea water by reason of the lowered pressure within the spout wall, or by the violence of the winds; or the impression of rising water may be illusory, which is doubtful, considering the number of observations reporting it. Almost as frequently a basinlike depression has been mentioned, as though the water had been hollowed by rotary action, or by a violent descending air current, similar to the one already referred to in the preceding paragraph. While this depression sometimes apparently has been noticed in fully developed thin-walled spouts, yet it has been plainly seen on a few occasions in surface whirls that have passed in close proximity to vessels.

*The cascade.*—Similar to the débris-laden ground squall surrounding the foot of a tornado is the cascade, bush, or "bonfire," as it is sometimes called, enveloping the base of a waterspout. This is composed of dense vapor and spray hurled upward and outward from the agitated region, sometimes to the height of 100 feet or more.

LITERATURE CITED

(1) Hurd, Willis Edwin. Waterspouts. North Atlantic Pilot Chart, August, 1928.
(2) Humphreys, W. J. The Tornado. Mo. Wea. Rev., Dec., 1926, 54: 503.
(3) Hellmann, Von G. Wasserhosen auf dem Atlantischen Ozean.
(4) Gibson, H. B. Waterspouts in the Gulf Stream in Winter. American Meteorological Journal, vol. 3, pp. 119–127.
(5) Russell, H. C. Waterspouts on the Coast of New South Wales. (Paper read before the Royal Society of N. S. W., Aug. 3, 1898.)
(6) Bigelow, Frank H. The Waterspout seen off Cottage City, Mass. Mo. Wea. Rev., July, 1906, 34: 309.
(7) Ibid, vol. 34, p. 314.
(8) Nature, vol. 110, Sept. 23, 1922, p. 414; Mo. Wea. Rev., April, 1923, 51: 209.
(9) Franklin, Benjamin. Philosophical Papers, Vol. II, p. 53.
(10) Monthly Weather Review, vol. 30, 1902, p. 302.

## THE COLORADO RIVER SITUATION

By JAMES H. GORDON,

[Weather Bureau Office, Yuma, Ariz]

The student of meteorology can hardly let his interest in precipitation cease with the fall of moisture to the ground. He must care something what becomes of it, what it does and what is done with it on its way back toward to sea. So we find the Weather Bureau studying streams and rivers. The forecasting of stream stages, especially at time of flood, is hardly less important than forecasting the weather. Interest extends to stream flow for the purposes of navigation, for power development, and, in arid regions, for irrigation.

The Colorado River has long been one of the streams in which the Weather Bureau has taken an interest. Its flood problems are complex and serious. Its possibilities for power development are tremendous. Its use for irrigation is very important. Its waters are so greatly desired in "the land of little rain" that great cities will lift them over a massive mountain range to supply their needs.

It is not to be expected that the development of a river in which seven States are directly interested can be accomplished without battles over conflicting rights. The past eight years have seen such battles waged over the waters of the Colorado. And the war is not yet ended. The following paper is an attempt to discuss, as fairly as one man may see them, the essential facts of the present situation as regards flood control and use of the waters of the Colorado River.

The Colorado River is a resource of tremendous importance not only in the Southwest but to the whole Nation. It is estimated that development in the lower basin alone, from hydroelectric power, from reclamation of desert land by irrigation and from growth of cities made possible, may well represent a potential wealth of $14,000,000,000. It is a big proposition. To get the utmost from it there is need of a carefully worked-out plan of development. It is already bringing up questions of national policy that are of the utmost importance. National and State rights are involved. Care must be taken that injustice does not creep in. So far nothing has been done that will interfere with the carrying out of a carefully-considered, well-ordered plan to make the most of what the river can give.

The base of the situation is, of course, the river. It is not one of the great rivers of the world or even of the United States. It carries no commerce. Its average annual discharge of some 17,000,000 acre-feet of muddy water is barely 2 per cent of what the Mississippi can boast. The flow of the Nile is four times as great. The importance of the Colorado River lies in the value of its water for irrigation in an arid land and its tremendous potentialities in the development of hydroelectric power.

In the Colorado River Basin are some 120,000,000 acres of arid land, (Fig. 1), land with precipitation averaging less than 10 inches a year. Over thousands of square miles the rainfall averages less than 5 inches a year. For the entire basin the average depth of run-off is less than an inch and a half a year. The flow of the stream varies greatly from season to season. The annual discharge, as measured at Yuma, has ranged from ten to twenty-six million acre-feet in the last 26 years. The maximum flow normally comes in June with discharges occasionally reaching 200,000 second-feet. Not infrequently the late summer flow is barely sufficient to meet present irrigation demands.

For a thousand miles through its vast desert empire the river flows at the bottom of mighty canyons, as useless to the thirsty land as one of its own mirages. Only in the river valleys through which tributaries flow to join the main stream are irrigable areas. Along the lower river, after it has emerged from the deep canyons, re other areas that may be irrigated to advantage. Of the 120,000,000 acres of arid land in the Colorado River Basin there are perhaps 10,000,000 acres which might be classed as irrigable.

In the early days the chief problem of the Colorado was one of transportation, getting the wagon trains across. As river traffic developed low water and shifting sand bars tried the souls of steamboat men. Bigger problems appeared with the development of the Imperial Valley. Early in the sixties an Army engineer had seen

the great possibilities of the Salton Sink, a waterless desert, and the near-by Colorado. More than a million acres of land lay below the river level. Old overflow channels offered canals almost ready-made. In 1902 the engineer's vision became a reality. Water flowed down the old Alamo River Channel and into the canals of the newly named Imperial Valley. Development was rapid. Cities sprang into being. Then came the break. The whole river left its old course and flowed into the valley, flowed unchecked for more than a year. The closing of that break was a great achievement. But ever since there has been the threat of another break, a break that might be even harder to close.

The lowest stages of the river normally come in the late summer while the demand for irrigation water is still heavy. More than once water shortage at this time has threatened disaster to the crops.

We hear much of the tremendous fertilizing value of silt left by the Nile. The Colorado River mud is not looked upon as a blessing. It is estimated that 22,000,000 cubic yards of silt enter the canals of the Imperial Irrigation District annually. Quite a proportion of this is deposited in the canals and ditches and must be removed. The annual bill for this removal is close to a million and a half dollars.

The only easy way to run water from the Colorado River to the Imperial Valley is through Mexico. When development of the Imperial Valley began permission was secured from the Mexican Government to run it through Mexico, at a price. Mexican lands were, at any time, to be entitled to one-half the flow of the canal. At seasons of low water the Imperial Valley has been ill able to spare one-half of its supply. To meet this situation and other disadvantages that have developed in running the water through a foreign country demand has grown for an all-United States canal.

These problems of the Imperial Valley, especially that of flood threat, have appealed strongly to the imagination of the people of the United States. Following the closing of the 1905 break Congress appropriated a million dollars to build levees that should prevent the recurrence of such a disaster. Surveys of the river showed that at several places along the middle course there were dam sites offering almost unlimited facilities for storage, storage that could guarantee flood control. Under congressional authorization the Bureau of Reclamation took up the problem of locating and studying the site which would best serve the purpose.

At that time the problems of the Colorado River seemed to be essentially the problems of the Imperial Valley. In 1920 legislation was introduced into Congress providing for the building of a great dam at or near Boulder Canyon, the site chosen by the Bureau of Reclamation, which should end the problems of flood, drought and silt for the Imperial Valley. An all-United States canal was also provided for. A huge power plant at the dam was to repay the Government the entire cost of the project.

According to the prevailing law over the West right to water in streams may be established by filing claim and putting the water to use. Such rights are not affected by State lines, are fundamental on a stream. Establishing the right referred especially to municipal use or for irrigation. Use for power development might be recognized also.

Very determined opposition to the building of a great dam at Boulder Canyon came from the upper-basin States. In 1920 these States had more than a million acres of land under irrigation. It was considered feasible to put water on 2,000,000 acres more, but this added development was not immediately practicable. It was feared that the building of Boulder Canyon dam would permit the establishing of water rights in the lower basin which might leave an insufficient supply for the upper basin in the years to come. Since the water originated in these States they felt that they had a peculiar right to all that was needed for their lands.

The claim of the upper-basin States was plausible. They were able to block action on the dam. Their opposition could be overcome only by guaranteeing that the construction of the dam would not deprive them of their water supply. Such guaranty could be given only by agreement of all the States in the Colorado River Basin. To meet this situation Congress authorized the calling of a conference of the seven States interested which should allocate to each State its rights in the flow of the river. The meeting was held at Santa Fe, N. Mex., in the summer of 1921. All of the States were represented. Every claim of the upper-basin States was recognized. Attempts to allocate water to the individual States failed. An average flow of 7,500,000 acre-feet a year was allowed to the lower basin. Permission to construct the Boulder Canyon Dam was included in the agreement.

The legislatures of six of the seven States ratified the so-called seven-State compact almost at once. After a bitter fight Arizona's Legislature, by one vote, failed to ratify. For this failure to ratify Arizona has been severely criticized. But she was logical enough. She asked simply what the upper States had asked, and been given; protection in her rights. Millions of acres of Arizona's lands lay only waiting water to become fruitful. As in the upper basin, development was not immediately practicable. California had already filed on an amount of water equal to *all* that had been allotted to the lower basin. Irrigation in Mexico, from the Colorado River, was increasing and, by use, establishing right to water. Power development along the Colorado River had long been considered one of Arizona's greatest assets. Ratification of the seven-State compact carried consent to the construction of Boulder Canyon Dam. Plans for this dam provided for great power development. In this development Arizona was given no right. Acceptance of the compact would leave Arizona shorn of both water and power rights. It is only fair to the other States to say that Arizona went to the seven-State conference poorly prepared to ask for water rights. She had been a State only nine years. She did not know her own needs and was in no position to impress these needs on others. Questions of power rights were not within the scope of the conference.

Arizona's stand appears to have been justified. The principle of her demand for water rights similar to those granted the upper-basin States has been recognized, but no division of water with California has been agreed upon. All the basin States have united in asking for a treaty agreement with Mexico limiting the water right which may be established there. All the basin States, except California, agree on the right of a State to realize revenue from water-power development such as is planned at Boulder Canyon.

The foregoing facts are the background for the present situation in Colorado River development.

There are to-day certain pressing problems in connection with the Colorado River that call for early solution. One of them is southern California's need for an increased water supply. Nature gave southern California a climate of peculiar appeal. Many people have gone there to

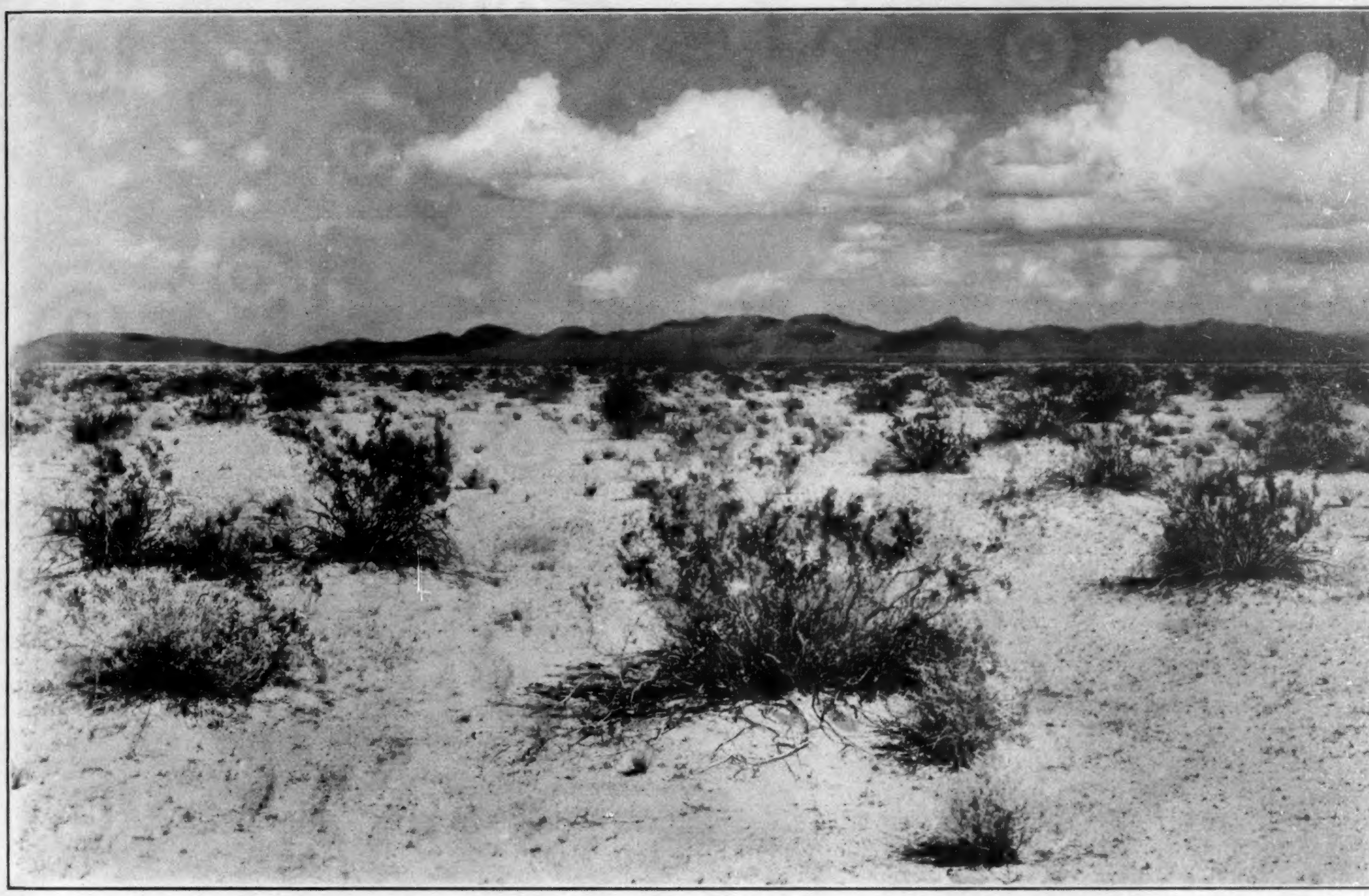


FIG. 1.—Typical of millions of acres of desert land in the Colorado River Basin needing only water to become fruitful

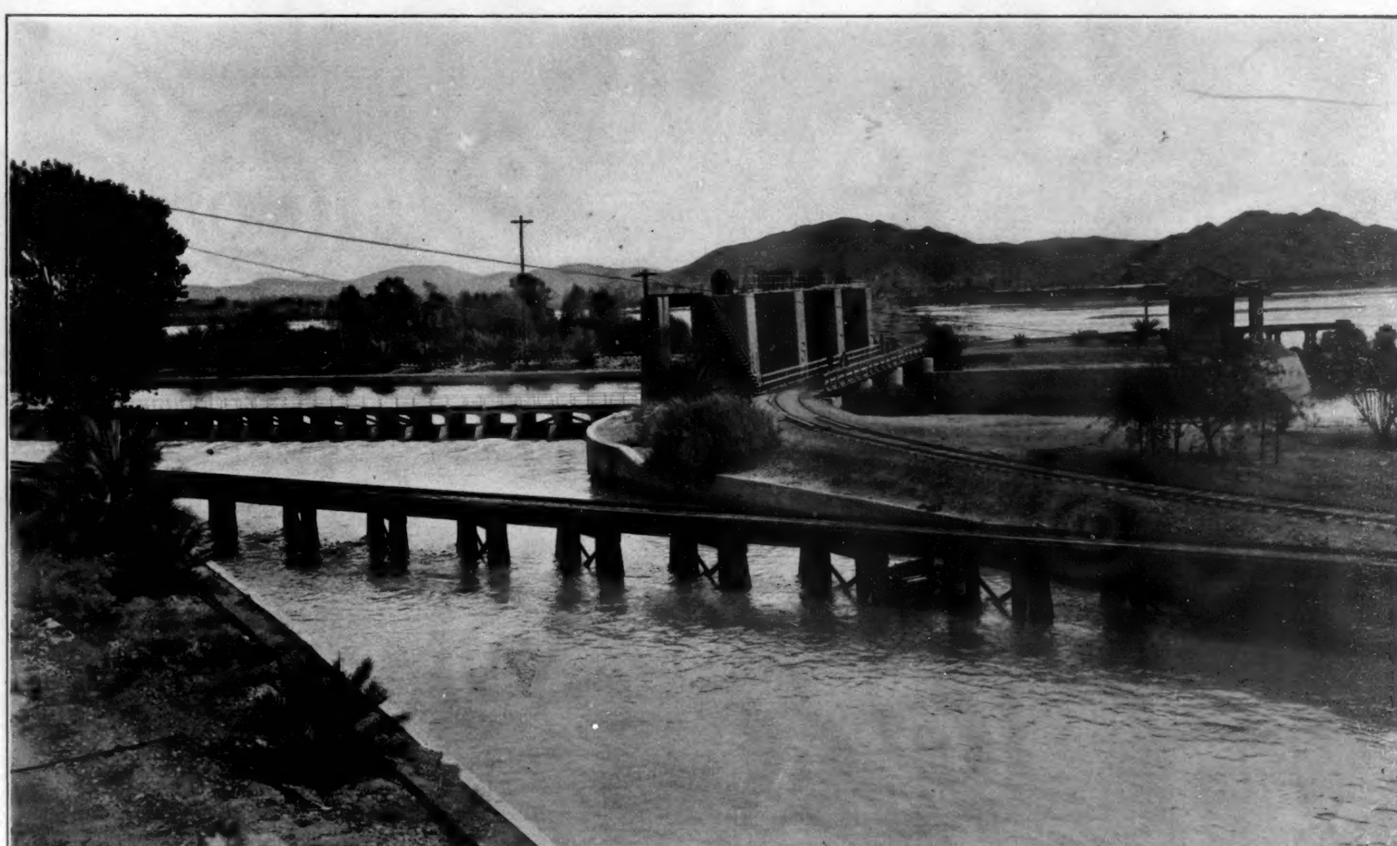


FIG. 2.—Canal intake fron desilting basin at Laguna Dam. Huge gates near the center of the view are raised every few days to sluice out accumulated silt in the basin

live because of it. Partly because of the climate, partly to keep pace with growing population, partly because of the discovery of great oil fields, partly because of rich tributary hinterlands, great industrial growth has come also. The climate has had a great part in southern California's growth. The climate, the great number of sunny days and the small number of rainy ones, set a limit on that growth. The problem of water supply is becoming serious. It is not yet serious in years of even normal precipitation but records of the past show series of years with decidedly subnormal precipitation. A repetition of such a period as that extending from 1895 to 1901 could hardly help but bring on a very serious water shortage. Ten years from now with increased demand from growing population and industry it would be more serious. In 30 or 40 years it might well mean a disaster of major proportions with losses running into a great many millions of dollars.

Further development of present sources of supply is possible but decidedly limited. Generally speaking southern California's present water supply, including that drawn from Owens River, is controlled by the same climatic conditions. A drought, when it comes, is likely to affect all sources of supply. Not only is there need of augmenting the present supply but it should be augmented if possible from a source not affected by southern California's droughts. The Colorado River, with the adequate storage offered by her dam sites, is about the only source to which southern California can turn. These same dam sites present opportunity for developing the tremendous amount of power that will be needed to lift 1,000,000,000 gallons of water a day over the intervening mountain range. Engineer's estimates call for some 400,000 horsepower to do the job. California has provided for the formation of a great water district of municipalities to handle the project. Cities as far south as San Diego and as far north as Santa Barbara could be served. It seems likely that the proposed system, including distribution to the various cities, will cost fully $300,000,000.

Plans have been offered for a system that would deliver water over the divide without pumping, using an intake far up the river, but the cost of such a project, as well as the engineering difficulties involved, are very great. The plan tentatively accepted calls for an intake near Blythe, approximately the nearest point on the river to Los Angeles. The climb to Shaver's Summit, near the head of the Coachella Valley, would be made in five lifts, aggregating about 1,400 feet, distributed along the first 75 miles of the route. Fifty to sixty miles of tunnel will be required. The first unit proposed would handle 300 second-feet of water—more than the Owens River Aqueduct is now supplying Los Angeles.

The combined filings of Los Angeles and San Diego on the Colorado River are 1,655 second-feet, which would mean 1,206,000 acre-feet a year. It will be a good many years before the cities of southern California can use as much water as that. If the estimates which the writer has seen are correct, the cost of delivering water over the divide, it will be decidedly practicable to use some of the water for irrigating purposes. There are rich orchard sections in southern California where the level of the water table has been dropping lower and lower. Demand exceeds the supply. It seems that an outside source of water must be depended upon to maintain even present development. It is almost, if not quite, as important to assure an adequate water supply for agriculture as for municipal use.

Imperial Valley has been facing the flood menace every year since 1906, has faced it bravely and won out. With improved equipment and increased knowledge of the problems to be met it is probable that the Imperial Valley could win out for many years to come. But no one knows. A flood in the Colorado as unprecedented as that in the Mississippi last summer might well be more than the valley's fortifications could resist. It probably is not necessary to explain that the consequences of a great break in the defences of the Imperial Valley is much more serious than a similar breach in the levees along the Mississippi River. The Imperial Valley occupies the southern half of a great basin or sink 90 miles long and from 10 to 40 miles wide. The bottom of the basin is 300 feet below river level and there is no outlet save over the top. Water escaping onto the lands along the Mississippi River drains off in the course of a few weeks. Water escaping into this great basin stays there until the sun dries it up. If the break could not be closed the basin would gradually fill up. It would make a very beautiful inland sea, quite impressive in the desert setting, but it would blot out half a million acres of rich farms and ten or a dozen pleasant, thriving towns. Because the grade toward the bottom of the basin is much steeper than the grade toward the sea, because the deep silt of the valley floor makes canyon digging easy and dam building very difficult the closing of a big break would present very grave problems. As to the need of a dam in the river which will guarantee that there shall be no such break there is no question.

You can fight a flood but you can not fight a drought. Hardly less important than flood protection for the imperial Valley is protection against water shortage. The late summer flow of the river has several times dropped close to the danger point in water supply. In the second week of September, 1924, the supply of water reaching the Imperial Valley was insufficient even to water stock. Losses were heavy. Banks and business houses as well as farmers faced almost a wiping out of their resources. Rains in northern Arizona and Utah brought relief in the nick of time. The Imperial Valley has no wells, practically speaking. Failure of water supply from the Colorado means absolute drought to the valley, save in the one small area where well drilling has been successful. Protection against water shortage is very essential.

Mention has been made of the valley's silt problem and the annual bill of a million and half dollars for its removal. From the canals and ditches. Ten years ago the Imperial irrigation district bought the right to take its water supply from Laguna Dam, 12 miles above Yuma. This is a diverting dam only and provides no storage, but it does provide a settling basin where the slow-moving water deposits a great proportion of its load of silt. (Fig. 2.) Water for the canals is "skimmed"; that is, drawn off the top of the basin, and, while still muddy looking, is much freer from canal and ditch-clogging material than water drawn directly from the river. The right of the Imperial irrigation district to take water from Laguna Dam has never been exercised, probably because the necessary changes at the dam and in the canal system would cost nearly $8,000,000.

There are disadvantages in the present arrangement for running the valley's water supply through Mexico. Having to share the water with Mexican lands is one. Another is in regard to water rights. Since the water, though taken from the river on the United States side of the border, goes into Mexico and is there divided with Mexican lands the water rights of the Imperial Valley

can have little or no standing in the courts of the United States. The water passes out of their jurisdiction. In the Imperial Valley and in the Coachella Valley, occupying the northern part of the Salton Sink, are some 270,000 acres of good land out of reach of the present canal system. A canal starting at Laguna Dam and following a higher grade could reach this land. The proposed All-United States canal would take care of these problems as well as that of silt. It is only a question of whether the benefits would justify the estimated cost of $41,000,000. Between the Colorado River and the Imperial Valley, in the United States, lies the great sand-hill area 40 miles long and 6 miles wide. The course of the All-United States canal, as surveyed, lies for 10 miles through the sand hills. All this distance it must be in a deep cut with maximum depth of 150 feet. When it is remembered that the width of the canal at the bottom will be 140 feet and that the banks, to hold in the soft sand, must slope back very gently one may get an idea of the immensity of the excavation required. An alternate route holding the grade of the All-United States canal could be built around the southern end of the sand hills by swinging 2 or 3 miles into Mexico. This route offers a saving in construction costs that is very material. It seems that it should be possible to work out some treaty arrangement with Mexico whereby the necessary strip of land could be secured. If a dam is built on the Colorado the United States would be in a position to guarantee a water supply for Mexican lands in exchange for concessions as to canal route. It should be possible also to put the water rights of the Imperial Valley in the position where they have the needed legal standing.

These are California's needs: Water for the cities of the coastal section of southern California; flood protection, drought protection, silt relief, and a new canal line-up for the Imperial Valley. The legislation taken up at the last session of Congress and passed by the House was written to meet these needs. It should meet them. Provision was made that the Government investment should be repaid by revenue from the sale of power. This repayment would be guaranteed by actual contracts in the hands of the Secretary of the Interior before construction began, repayment with interest within 50 years. Southern California municipalities and industries must take the power. There is no other considerable market. Eventually some two-thirds of the power will be needed to pump water over the divide, but it probably will be a good many years before that requirement reaches a peak, and other power dams may be ready to share the load. In effect southern California underwrites the cost of the project. Putting the power to profitable use is her problem.

Other needs of the lower basin are not so pressing as those just mentioned. Nevada can use little water. Arizona, on the other hand, has millions of acres of land to which water might conceivably be applied. The Grand Canyon of the Colorado is cut through a great plateau which forms the northern part of Arizona. Much of the central and southwestern portions of the State lie below the level of the river in the Grand Canyon. A tunnel driven under the plateau to tap the river at any one of several dam sites could bring water to nearly 4,000,000 acres of land. But the tunnel must be 80 or more miles long. The cost would be very great. It is not a feasible undertaking at the present time. No one can say that it may not be practicable at some time in the future. Another plan, on a less gigantic scale but involving considerable pump lift, would bring under irrigation more than a million acres of land in southwestern Arizona. It is doubtful whether land values justify this project at the present time but its practicability seems assured.

California's attempts to solve her problems in the Colorado River have brought her into conflict with Arizona and to a lesser extent with most of the other States of the basin. But it has been chiefly Arizona that has blocked action in Congress. Why? It is not that Arizona opposes flood protection for the Imperial Valley. It is not because she wishes that section to feel the pinch of drought. It is not because she begrudges Los Angeles and her sister cities a water supply. Granting California's needs and rights, Arizona asks equal consideration for her own. The allocation of water to the lower basin was not great enough to meet the estimated needs of both States. The original claims of both States have been modified. Both have made concessions. But California has set a figure below which she will not go and Arizona has set a minimum amount which she must have. The sum of the two minimum figures is 600,000 acre-feet a year more than the two States have to divide. Six hundred thousand acre-feet a year is enough water to turn more than 150,000 acres of desert into rich farms, enough to create wealth of from thirty to fifty million dollars for the State that has it. It is not a thing to be lightly given up.

One-half the proposed Boulder Canyon Dam will be in Arizona, one-half in Nevada. The two States ask for a revenue from power development equal to what they would receive if it were a private enterprise. California receives revenue from power development within her borders. New York State taxes the power development at Niagara Falls. It seems reasonable enough for Nevada and Arizona to ask for the same right. California, naturally enough, has opposed recognition of the right. Her power users, municipalities, and corporations would have to pay the tax. An amendment to the bill before the Senate, adopted near the close of the last session of Congress, provides that 37½ per cent of the profits of operating the power plant at the dam should be divided equally between Nevada and Arizona. It seems unlikely that there will be any profits during the 50 years that the dam is being paid for. The States might reasonably wait 50 years if there was assurance of a reasonable revenue after that time. At least the amendment is a recognition from the Senate of the reasonableness of the claims of Arizona and Nevada for a return from such a development as will be made at Boulder Canyon. Arizona is fighting not only for this case but for a precedent which shall govern in the development of 4,500,000 horsepower of hydroelectric energy that may be made along and within her borders.

A review of the progress made toward development of the Colorado River since 1920 is not very encouraging. Legislation before Congress is much the same as that introduced eight years ago. The truly vital needs of the Imperial Valley have not been met. The later recognized but just as vital needs of the coastal section of southern California have not been satisfied. The seven-State compact has not been ratified. There is little prospect that it will be ratified, without change. The program of river development adopted eight years ago has failed utterly to get results.

Does it seem unreasonable to suggest that a fresh start be made? A decided sentiment has developed opposing the fundamental principle of the seven-State compact, favoring a retention of the old law that water rights must be used to be retained. There is very good ground for ob-

jecting to the allocation of water to a State or section in perpetuity, regardless of use. Such water must waste until put to use by the section to which it is allocated. Such a waste extending over many years may well represent a very great economic loss to the Nation. Such an allocation as was made under the seven-State compact is contrary to the fundamental law of supply and demand. It is as indefensible as price fixing. It arbitrarily sets a limit on the growth of one section of the country in order that, at some time, if conditions are right, another section may develop. Is it not possible that a compromise between the old water-rights law and the new allocation idea may be worked out? Use should, of course, establish right to allocated water. Every 10 years, or perhaps at longer intervals, water to which right had not been established could be reallocated on the basis of need. Such a plan would fit in with the economic growth of the Nation. It would be flexible where the old plan is inflexible.

This would require a new seven-State compact. In the seven years since the old compact was drawn up much has been added to our knowledge of the river and its problems. Probably every one of the seven States of the Colorado River Basin could act more intelligently now. It seems that a new conference should be called and a new compact drawn in the light of our increased knowledge. Not only that, but provision should be made for a permanent body, made up of representatives of the States, to meet as need arose and act upon problems of river development. Arizona's fight for water rights should not properly be directed at California. California should not be asked to deny herself needed water to supply Arizona. The needs of Arizona should be met by a fair division of the flow of the whole river. The 600,000 acre-feet of water in dispute between California and Arizona could be far better spared from the abundance of the upper-basin States than by either one of the contesting States. At least it seems that a new seven-State conference should be able to work out a more equitable division of the water. On the surface it appears that there is not water enough in the river to meet the demands that will be made on it, in the course of time. Many irrigation engineers, however, maintain that with the return flow from irrigated lands it will be sufficient to meet all demands. Time only can settle this question. This and other problems must come up for settlement as development of the river procedes.

A few words on the proposed first step in Colorado River development seem in order. This would be the construction of a great dam at or near Boulder Canyon. The site is in a canyon 2,000 feet deep. At low-water level the width is less than 200 feet. To reach bed rock for foundations excavation at least 130 feet deep will be necessary. The dam itself, from foundation to parapet, is to be nearly 700 feet high, more than an eighth of a mile. The height above stream bed will be 550 feet, 200 feet higher than any dam now constructed. The capacity of the great basin behind the dam will be seven or eight times that of any present storage reservoir. The Colorado River brings down more than a hundred thousand acre-feet of silt a year. This will settle in the calm waters of the great lake above the dam. This deposit of silt piling up for a hundred years will not materially affect the storage and power value of the dam. Admittedly the stresses, strains, and pressures involved in such a mighty structure are beyond present experience. A commission of eminent engineers and geologists has been appointed, with the approval of the President, to study problems in connection with the proposed dam this summer. The result of the findings of this commission will be of very great interest to all who are concerned in the development of the Colorado River.

Arizona has opposed a good many things in the last seven years. The great dam proposed for Boulder Canyon is one of them. She has within her borders a splendid object lesson in the maximum utilization of a stream for power development as well as for irrigation. The Roosevelt Dam, at the junction of the Salt River and Tonto Creek, furnishes the principal storage. Three power and substorage dams have been built and a fourth soon will be started to utilize nearly every foot of the fall between the base of Roosevelt Dam and the level of the Salt River Valley. It is a paying proposition. It looks to the people of Arizona as though some similar plan could and ought to be worked out for the Colorado with a water supply and drop more than ten times as great. The Boulder Canyon Dam site is near the foot of the drop. Its tremendous storage will be no help to power development on most of the river. When dams are built farther upstream, as they will be, much of the storage provided for at Boulder Canyon will become useless. Storage should come at the head of the slope. Substorage dams and power plants should be built as near the market as possible.

To fit in with a comprehensive plan for the utmost use of the river it seems that the dam at Boulder Canyon should be a substorage dam. This would mean a smaller dam, but a structure 100 feet lower would provide all reasonable flood protection, would assure adequate water supply, and permit power development enough to meet essential demands for many years to come. As dams were built above, power development at Boulder Canyon would increase and flow regulation could be more perfect. As demand justified, other power dams could be built, a series of steps, all using the regulated flow from storage at the head of the slope. Certain engineers of high standing urge the construction of two dams near the head of the slope, one at Flaming Gorge and the other at the Dewey Dam site, as the first step toward development of the river. These dams are said to offer no great problems of construction and would not only supply a considerable storage at the head of the slope for power development, but would very greatly simplify the problem of building a dam at Boulder Canyon by giving at least a partial control of the river.

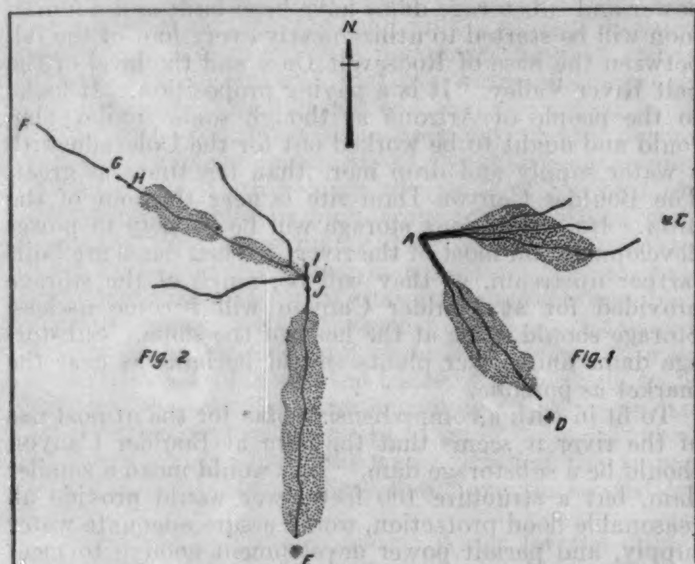
This is the Colorado River situation as it appears to one who has tried to see it not as a citizen of California or Arizona but as a citizen of the United States. It seems that there should be a plan worked out for the river's development and use, worked out by the finest engineers the United States can boast. One can hardly help a thrill over the rich irrigated lands of the Imperial or Salt River or Yuma Valleys, reclaimed from the desert. We hope to see these areas grow mightily. We hope to see the tremendous power of a river that carved out the Grand Canyon and carried hundreds of cubic miles of earth and sand and rock from the mountains to the sea turned to man's account. It can be done. We may start it. We would like to think that men, in the years to come, will believe that we started it wisely.

# GROUND MARKINGS BY LIGHTNING

By F. F. PAYNE[1]

[Totonto Golf Club, Long Branch, Ontario, Canada, July 14, 1928]

On June 23, 1928, during an electric storm, and while several men were taking shelter in a shed, a green on the course of the Toronto Golf Club was struck by lightning. The grass being exceedingly short, the markings left afforded a unique opportunity for study and measurement. The distance from the shed to the green is 100 yards. The flash was described as blinding and the thunder as deafening. Immediately after the flash, smoke and




steam were seen rising from the green, and upon examinarion it was found littered with a small quantity of earth and grass roots. These came from some deep holes and grooves, and the grass at the edge of these was slightly burned. Elsewhere the wet grass was only withered by heated moisture. Definite lines forming angles soon appeared, these lines being indicated by continuous withered grass. Upon each side of the main lines or legs of the angles there were also wide patches of withered grass along the greater part of their length. In the case of some less definite lines the side grass was uninjured. It is evident that the markings shown in Figures 1 and 2 were caused by the same flash but the grass between *A* and *B* was untouched. Possibly the flash divided when near the ground. At *A* was a deep, round hole and for a short distance lines diverging from it were wide and deep, while at *B* the earth was showing but the scoring was not deep and a hole immediately at this point was not visible. There were small holes, however, north and south of this point 3 inches apart, slanting northward and southward, respectively.

The main legs or lines were more or less scored, showing earth as though a small bullet had ricocheted along these lines, while other lines showed only withered grass.

The most remarkable discovery was that of short round tunnels at the end of the lines at *C*, *D*, and *E*, also a short distance up the line, *B* to *F* at *G*. The course of the current was evidently outward as the entrance holes of these tunnels were slightly cut, while the escaping holes were covered with dead grass and were only discovered by passing a pliable stick through the tunnels. The grass above all these tunnels remained green. At *H* (Fig. 2) there was a deep, narrow hole sloping slightly toward the northwest.

After careful examination the impression left was that upon striking the ground at *A* and *B* the fluid had splashed and bounded outward down the lines shown in the diagram.

The following measurements are appended:

Upper short groove at *A*, 6½ inches long, ⅞ inch wide.
Lower short groove at *A*, 7 inches long, ⅞ inch wide.
Width of tunnels at entrance, ¼ inch.
Length of tunnels at *C*, 12½ inches; at *D*, 4 inches; at *E*, 3½ inches; at *G*, 3 inches.
Extreme depth of tunnels, 1 inch.
Length of lines, *A* to *C*, 44 inches; *A* to *D*, 39 inches; *B* to *F*, 61 inches; *B* to *E*, 40½ inches.
Distance of small hole at *H* from apex at *B*, 38 inches.
Hole at *A*, ¾ inch in diameter and 5 inches in depth.
Depth of hole at *H*, 4 inches; diameter, ¼ inch.
Depth of hole at I, 4 inches; diameter, ¼ inch.
Depth of hole at *J*, 3 inches; diameter, ¼ inch.
Distance from *A* to *B*, 43 inches.
Distance from *A* to bamboo flagpole, 15 feet.
Distance from *A* to nearest tree, 150 feet.

[1] For many years secretary of the Meteorological Service of Canada; now retired.

# FRANKLIN'S KITE EXPERIMENT AND THE ENERGY OF LIGHTNING

By ALEXANDER MCADIE

(Blue Hill Observatory, Mass.)

SYNOPSIS

Franklin's kite experiment as described by him in the well-known letter to Collinson, dated October 19, 1752, naturally challenged the attention of the scientific world and established the electrical nature of lightning. Efforts to get accurate dates and details have proved unavailing thus far, although it would seem that in contemporaneous journals and correspondence some corroborative evidence must exist.

The common belief that the kite experiment paved the way for the introduction of the lightning rod is disproved by Franklin's own use of the rod and his clearly expressed views as to the identity of lightning and electricity, at earlier dates.

Perhaps the most promising method of obtaining knowledge of the nature of lightning is the duplication by artificial means of high voltage discharges having considerable current and very steep wave fronts. Such work is now carried on by the General Electric Co. in its high tension laboratory at Pittsfield, Mass., under the direction of Mr. F. W. Peek, jr. These discharges may well be called *near-lightning*, and illustrate well the peculiar characteristics of the natural discharges whether we regard them as oscillatory or unidirectional.

There has been a tendency in scientific circles to depreciate the importance of this line of attack and to give preference to values obtained on theoretical grounds and measurements which seem open to criticism. Attention is called to an error in a published statement critical of our estimate of the energy of an average flash; and it is shown that confusion has arisen from the use of units with similar initials but quite different values.

Some approximate measurements of the energy in kilowatt-hours are given, based upon fusion of kite wire at Blue Hill Observatory, and the voltage is shown to be of the order of 13,000,000 as compared with 10,000,000,000 given by so eminent an authority as C. T. R. Wilson. Kite experiences at a number of Weather Bureau stations are summarized as confirmatory of the lower values.

The importance of a study of the side discharges or split-off flashes is urged as contributing to a knowledge of the process of breakdown of the dielectric, the origin of the path, the concentration of electrons producing ionization, and the nature of the explosive effect.

In a short letter to C. C. Esq (Cadwalader Colden?) dated 1751 without month or day, Benjamin Franklin tells of possessing five bottles (Leyden jars) containing 8 or 9 gallons each; two of which when electrically charged were sufficient for all his experiments. He concludes with "bottle may be added to bottle ad infinitum and all united and discharged as one." Then follows a characteristic Franklin deduction: "The greatest known effects of common lightning may without much difficulty be exceeded in this way." He overlooked the limits of insulation.

As early as November, 1749, he had come to the conclusion that since the effects of lightning and the electricity of static machines (frictional glass and sulphur globes) and Leyden jar discharges were similar in so many ways, then lightning must be electrical in character. His "Opinions and conjectures, based on experiments made in Philadelphia in 1749," and his "Observations and suppositions toward forming a new hypothesis for explaining the several phenomena of thunder gusts" (1749) were transmitted to Europe, chiefly through Peter Collinson, Esq., F. R. S., London, and attracted much attention.

In September, 1752, Franklin erected on his own house an iron rod. The exact date of the kite experiment we have not been able to ascertain, although many authorities on Frankliniana have been consulted and search made of collections in Philadelphia, Boston, and Worcester. In Franklin's own newspaper, the Pennsylvania Gazette, there is no mention of any kite experiment until late in October, under date of October 19, 1752, when there was published the well-known letter which begins with a reference to "frequent mention in public papers from Europe of the success of the Philadelphia experiment for drawing the electric fire from clouds by means of a pointed rod of iron erected on high buildings, etc."

He goes on to say that "the same experiment has succeeded in Philadelphia though made in a different and more easy manner"; and then follow directions for making a kite and a description of what will happen when the kite is raised during a thunder gust. There are three known copies of this letter. No specific date is mentioned in any of them, which is strange, for in his cloud experiments Franklin noted not only date and place but also the hour. In the copy which my predecessor, the late Prof. Lawrence Rotch, purchased are the words "anyone may try," words which are not in the letter published in the Philadelphia Transactions, 1752, page 565, and dated October 1, 1752. Nor is it stated explicitly in any of the letters that the experiment was actually made. A final paragraph in the Transactions letter, not found in the others, reads:

> I was pleased to hear of the success of my experiments in France and that they there begin to erect points upon their buildings. We had before placed them upon our academy and statehouse spires.

From what precedes we infer that the rod antedated the kite. Accounts in most textbooks lead one to believe that the kite experiment led to the invention and adoption of the rod.

There is nothing in the correspondence between Franklin and Kennersley in the first half of 1752 that hints at any kite experiment; and as their relations were friendly and Kennersley had loaned Franklin a brimstone globe it is puzzling to understand why so crucial an experiment was not mentioned. It is true that Franklin in his autobiography says that the kite was flown in 1752, but this was written when he was an old man, largely from memory; and it seems to us that he may have confused his experiments made on the electrical nature of clouds in 1753 with the kite experiment. The date given in the Britannica, June, 1752, is probably erroneous, a confusion with June 6, 1753, when between 5 and 7 p. m. Franklin watched a cork ball swing to and fro between two jars, one electrified by the insulated rod (or accumulator of the air potential) and the other charged by his frictional machine. An interesting deduction based upon these experiments of 1753 was:

> So that for the most part in thunder strokes it is the earth that strikes into the clouds and not the clouds that strike into the earth.

One may compare this with our latest views on the mechanism of a thunderstorm (Dr. G. C. Simpson, Proc. Roy. Soc. vol. 114, 1927, p. 380), where it is shown that lightning "can not start at a negatively charged cloud" and therefore "any discharge between the ground and this [negatively charged] part of the cloud must start on the ground and branch upward." Furthermore, in another paper from an examination of 442 photographs Simpson shows that the "preponderance of the lower clouds from which lightning discharges proceed are positively charged." (Proc. Roy. Soc. A vol. 111, 1926, p. 67.)

As stated above, the rod experiment of drawing or extracting electricity from the atmosphere during thunderstorms aroused great interest in Europe. In London the summer of 1752 was cool and damp and only one thunderstorm, that of July 20, afforded opportunity to test the hypothesis. Watson obtained no sparks; but Canton, Bevis, and Wilson succeeded. The experiments in France were more successful, and it was as an amplification of these that the kite letter was written and made public. So far as we can at present determine, the first individual to observe a spark from an insulated conductor during a thunderstorm was the old soldier Coiffier on guard Wednesday May 10, 1752, about 2:20 p. m. at Marley. The story was told by M. D'Alibard to the Academy of Science at Paris, May 13.[1]

It is a far cry from Marly, 1752, to Pittsfield, Mass., 1928; from the small spark due to an induced charge on an insulated conductor to the near-lightning discharges obtained by Mr. F. W. Peek, jr., of the General Electric Co., illustrated herewith. (Fig. 1.) Figure 2 is a photograph of a natural lightning flash made by A. H. Binden. When Franklin used the electrified rod, the difference of potential between the point and the earth probably did not exceed 5,000 volts even at the maximum just before the flash occurred. In the case of the artificial flash the potential difference is 3,600,000 volts. We may estimate this as about one-third the voltage of an average lightning discharge 300 meters in length. In preliminary experiments Peek found for a meter spark a voltage of about 330,000 volts; but as will appear later, there is no assurance that multiplying this value by length will give a true value for a natural discharge.

Briefly, the Pittsfield experiments are the outcome of studies made for the protection of high-voltage transmission lines. Peek has measured lightning voltages on such lines in a mountainous region (Colorado) and found

[1] Je suis allé chez Coiffier qui déja m'avoit dépêché un enfant que j'ai rencontré en chemin pour me prier de venir; j'ai doublé le pas à travers un torrent de grêle. Arrivé a l'endroit ou est placée la tringle coudée, j'ai présenté le fil d'archal, en avançant successivement vers la triangle, à un pouce et demi ou environ; il est forti de laeringle une petite colonne de fer bleuâre sentant le soufre, qui venoit frapper avec une extrême vivacité le tenon du fil etc. etc. (Extrait d'un Memoire de M. D'Alibard.)

line potentials as high as 500,000 volts, while insulator flashovers by lightning have occasionally indicated voltages as high as 1,500,000 or more. In various papers read before electrical engineering societies Peek has given full descriptions and details of the apparatus used. (See High Voltage Phenomena, Journal of Franklin Institute, January, 1924, September, 1924, November, 1925, and Smithsonian Report, 1925, p. 169–198.) Large wooden posts can be split by this near-lightning; and in fact the phenomena of lightning can be duplicated on a scale, not greatly reduced from that of the natural results. By the use of models representing cloud capacities and transmission lines, Peek found that when a flash occurred 1 per cent of the model cloud's voltage was induced on the model line.

The induced voltage being determined, the indicated voltage of the lightning was found to average about 100,000,000 volts. He states that the lightning voltage during a storm will of course vary over a very wide range, sometimes much higher, but generally lower than the value above. It has been observed that during a severe thunderstorm there may be many induced strokes at very low voltages, a less number at moderate voltages and so on to the very few at the extreme voltages. These values indicate a gradient of 330 kv/m in the most dense part of the electric field where the flash occurs, and a gradient of less than 100 kv/m at a distance of 500 meters. The current is of the order of 80,000 amperes and the energy 13,500 kilowatt-seconds or 3.8 kilowatt-hours. To express this in homely terms, the energy of an average flash would be sufficient to operate an automobile about 5 miles or an electric toaster for a day. The time of dissipation of the energy is all important and this will also determine the explosive and destructive effects.

We can not here give details of construction and measurements. Most lightning flashes are impulse discharges, having steep wave fronts. Assuming a height of 300 meters, a cloud area of 10,000 square meters, and an ohmic resistance of 1,000 ohms the capacity will be approximately 25 by $10^{-7}$ millifarads and the inductance 0.0005 henry. The time may range from .01 second to .000001 second. In most cases lightning is well described as an explosive effect of electrical energy. An exceedingly small time will give for the power involved something like 100,000 kilowatts.

The values given by Peek have been criticized by Dr. G. C. Simpson as much too low for an average flash. Possibly flashes are longer in Great Britain than in the United States, and perhaps the cloud areas are larger. On the one hand we have Peek's values of 6 coulombs (or 18 by $10^9$ E. S. U.) while Simpson upholding Wilson's estimates makes the values about seven hundred times larger. Thus the energy of an average British flash would be about 3,000 kilowatt-hours. In homely figures as given by Simpson (Meteor. Mag. July 1927, p. 135):

> One lightning flash an hour on Professor Wilson's estimate would produce all the electrical power required by a modern industrial city of 100,000 inhabitants, 24,000,000 British thermal units. Thus a large generating station is more suitable for comparison with a thunderstorm than an electric toaster.

A mistake was made in printing British thermal units when British trade units were meant. Twenty-four million thermal units would be only 7,034 kilowatt-hours; whereas trade units would be 24,000,000 kilowatt-hours. Incidentally our electrical engineers tell me that this estimate is much larger than is found in their practice.

It is difficult to determine just what the concentration of charge is at the point of discharge at the given microsecond. Again, the polarity of the cloud as a whole must be considered, as one portion may be positive and elsewhere negative. Thus T. W. Wormell (Proc. Roy. Soc. A. vol. 115, 1927, p. 455) holds that while in most cases the thundercloud is of positive polarity there can be such a distribution of electric field as to indicate that the cumulo-nimbus is often bipolar; that is, upper portion positive, lower portion negative. Schonland and Craib (Proc. Roy. Soc. vol. 114, 1927) state that of 18 thunderstorms studied by them only 1 was of negative polarity. Sudden changes of field due to distant lightning were predominantly negative and those due to near discharges predominantly positive. Their results indicate that thunderclouds are bipolar, upper pole positive and lower pole negative. Their mean value for 82 lightning discharges was 94 coulomb kilometers which they consider as satisfactory in magnitude with the 148 coulomb kilometers found by Wilson.

Doctor Simpson in a letter to the writer doubts if a flash ever starts at a less height than 3 kilometers. This seems to us more like a maximum than average value. Wilson's values are determined by integrating the volume charges before and after the flash but the method is open to objection inasmuch as the changes are incessant and their relations can not be differentiated. The field values may even undergo reversal within short distances.

Doctor Simpson points out that values of potential gradient made at the ground can not indicate true flash energy since they give no evidence as to field strength. He holds that the discharge produces its own field as the channel along the discharge passes bores its way through the air. Probably he is right; but this would lower the required voltage.

As a partial and no doubt very imperfect contribution to the subject, I have gathered together a number of cases where kite wires have been struck by lightning. At Blue Hill we have tried to fly kites during light thunderstorms; but the practice is dangerous and for self-evident reasons experiments have not yet been carried as far as they might be under different conditions. At other places kite wires have been struck and the following abbreviated list may serve as illustrative of ground phenomena at such times.

1. Blue Hill: Lower kite 700 meters high; kite wire out 1,600 meters. About 600 meters fused. Weight 3,600 grams. Energy of fusion at 1,800 calories per gram equals 6.48 by $10^6$, or 7.5 kilowatt-hours. We estimate the current strength as 27,112,320 watt-seconds, and with a time of 0.001 second and resistance 700 ohms, the current would be 6,224 amperes and the voltage would be 1,400,000. On the other hand, a short time like 0.0001 second would indicate a voltage of 13,000,000 and energy 25 by $10^6$ kilovolt-amperes. Even under such conditions the voltage is less than the $10^9$ given by Wilson; and the coulombs 6 as against 50 or 100.
2. Ellendale: Six kites and 6,500 meters of wire out; 3,000 reeled in as the thundercloud approaches. Lightning strikes and the wire is not fused but discolored and distempered.
3. Royal Center: 1,300 meters of wire vaporized. Convection vigorous enough to cause thunderstorms only below 2,800 meters.
4. Ellendale: 2,200 meters of wire out. Upper section between second and third kites struck; wire blackened and distempered and splice joints melted.

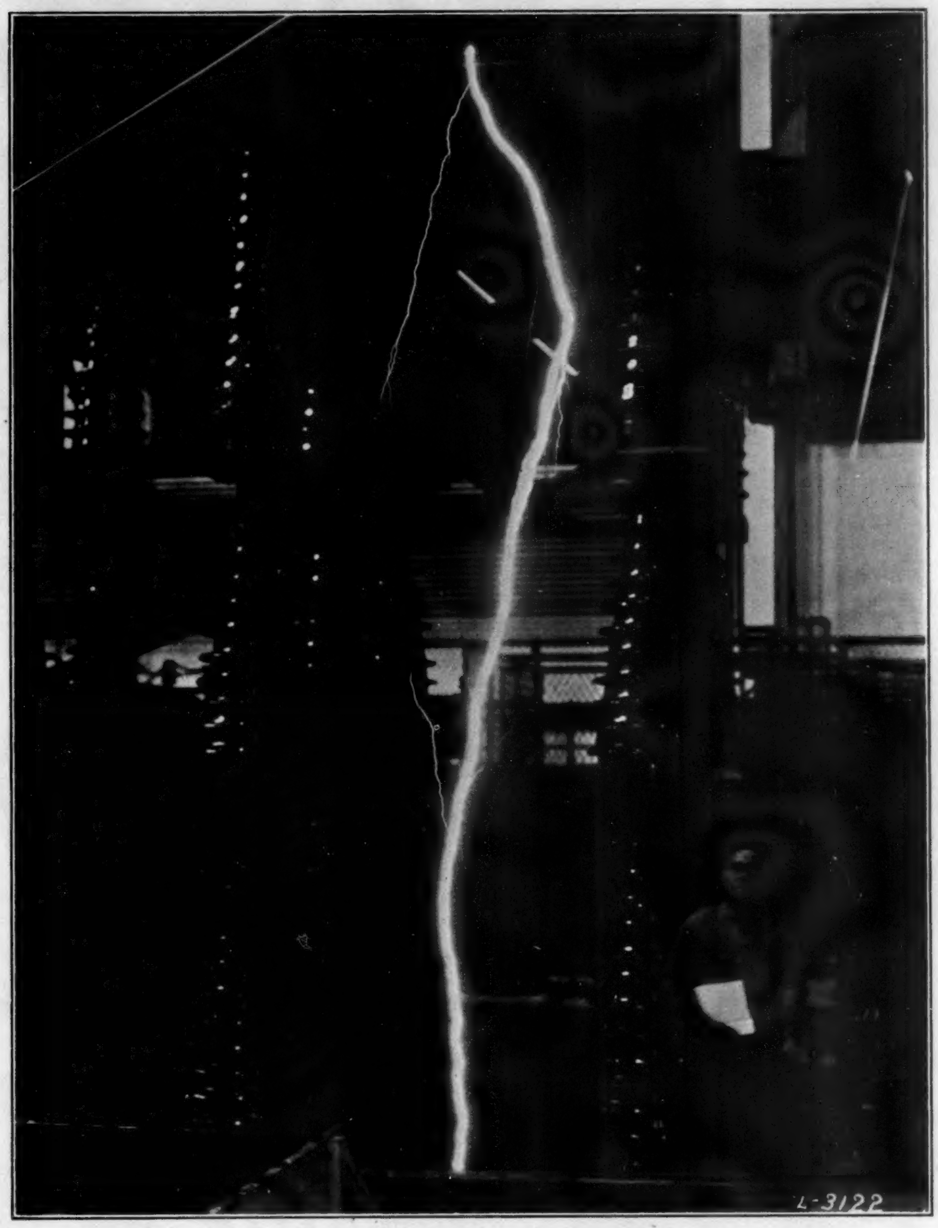



FIG. 1.—Near-lightning flash, 3,600,000 volts. F. W. Peek, General Electric Co.

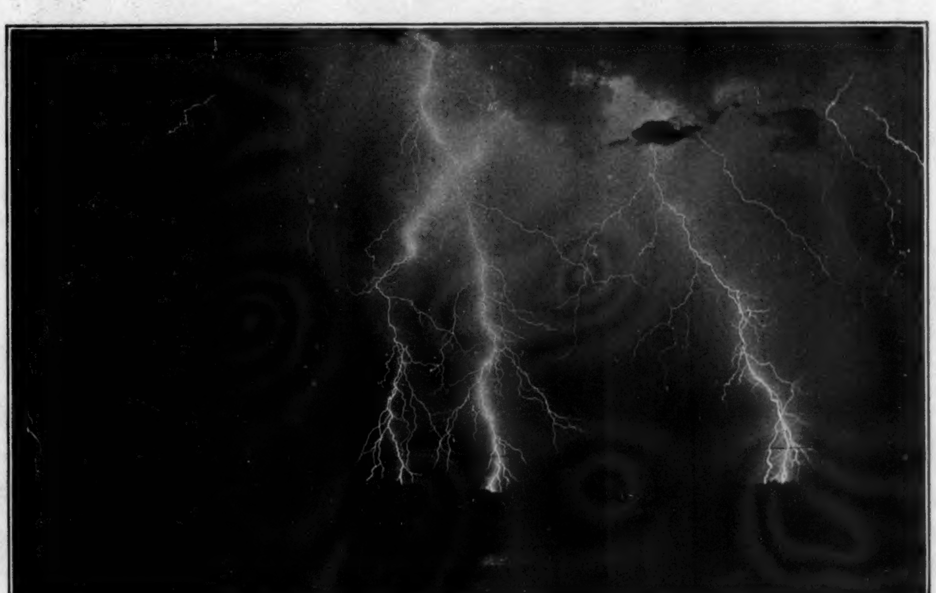


FIG. 2.—Natural lightning flash photographed by A. H. Binden

5. Drexel: Voltmeter showed in excess 50,000 volts for altitude 1,600 meters. Steady stream of brilliant sparks jumping 10 centimeters. Thunder first heard at 8.33 a. m. At 9.23 flash of lightning and thunder; 4,000 meters of wire out. Effect on wire as follows:

| Length from head kite (meters) | Diameter of wire (millimeters) | Condition |
|---|---|---|
| 0 to 800 | 0.9 | Destroyed. |
| 800 to 1,600 | 1.0 | Brittle like glass. |
| 1,600 to 1,900 | 1.0 | Dark blue. |
| 1,900 to 2,075 | 1.0 | Yellowish brown and dark blue. |
| 2,075 to 2,260 | 1.0 | Very dark blue. |
| 2,260 to 3,600 | 1.0 | Apparently not affected. |
| 3,600 to 3,680 | 1.1 | Light brown. |
| 3,680 to 3,800 | 1.1½ | Dark brown. |
| 3,800 to 4,000 | 1.1½ | Dark brown to dark blue. |

The string attaching head kite to wire was burned. That portion of the wire within the lower stratus cloud (below 1,000 meters) showed no ill effects from lightning, whereas that portion between base of cloud and earth (650 meters) was considerably affected in spite of the fact that it was wire of larger diameter, and therefore less resistance. The wire in the dry air (2,300 to 1,300 meters) between the two clouds layers was either entirely destroyed or rendered unfit for use. It is evident that the electric charge originated in the upper cloud layer and much of it passed along the wire into the lower cloud. A portion continued to earth but did not affect the wire because of the moisture on it, but did injure the wire in the drier air below. Thus an airplane might form part of the path of discharge. (See Supplement No. 10, M. W. R., 1918, pp. 5–6.)

6. Broken Arrow: 1,800 meters out; three kites. Stratus cloud 400 meters high. Lightning strikes head kite and completely destroys wire from kite to reel house leaving along the path a discharge a streak of thick yellowish brown smoke. If this discharge occurred in 0.001 second, the voltage is not far from 3,000,000, or about that of the artificial near lightning of Peek. Compare this with the next case.

7. Drexel: 3,535 meters of wire, except 20 or 30 near the reel, vaporized. The lower portion fused.

8. While not a kite wire record, it may be mentioned that on April 16, 1926, an airplane carrying eight passengers going from Paris to London was struck near Beauvais. A large patch of fabric was torn out, the compass demagnetized, one of the main spars scorched, all bondings fused, and one aileron badly damaged.

Doctor Dorsey has advanced the theory that there are electronic darts, or localized stream lines of electrons and that a positive stroke advances by a series of steps depending upon the occurrence of free electrons. Branching is to be expected; while in a negative stroke the electrons advance in a mighty rush. He objects to Doctor Simpson's deductions from the preponderance of negative polarity in side-split branches, as shown in many photographs. Inspection of the 3,600,000 volt flash herewith shows, curiously enough, split-off discharges in both directions from the same flash.

Humphreys has calculated (Physics of the Air, p. 396) in the case of a hollow tubular conductor crushed by lightning and assuming certain temperatures, an amperage ranging from 19,470 to a maximum of 100,000. With the latter value and assuming a megadyne pressure on the inner tube, there results a pressure of 2,638 by $10^4$ dynes per square centimeter or roughly 26 atmospheres. He warns, however, that these are rough estimates and "that this particular discharge presumably was exceptionally heavy since it produced an exceptional effect." He also quotes Pockels estimate of 10,000 amperes. Mr. S. A. Korff, of the General Electric Co., has called my attention to Steinmetz's estimate of the energy as $10^1$ watt-seconds or 2.8 kilowatt-hours which is only a thousandth of Wilson's value. Larmor has estimated the energy as 28 kilowatt hours. (Proc. Roy. Soc. 1924, Vol. 90, p. 312.) Since the voltage breakdown of air is 9 by $10^9$ volts it seems likely that estimates exceeding this are too high; and as the breakdown is probably progressive, values of 1.2 by $10^7$ volts are ample, thus bringing the energy value to approximately 28 kilowatt-hours.

For the benefit of the lay reader then we may say that in our opinion the energy of an average flash of lightning does not run much over 10 kilowatt-hours or, let us say, enough to operate three ordinary toasters (300 watts) for 10 hours.

## PHENOMENA PRECEDING LIGHTNING

By ALEXANDER MCADIE

(Blue Hill Observatory, Mass.)

In the Meteorological Magazine June, 1928, p. 113, Mr. R. S. Breton, writing from Tung Sung, Southern Siam, states that on a number of occasions he has noticed a sharp "vit" or "click" accompanying lightning that has struck something in the immediate neighborhood, preceding the thunder by a perceptible fraction of a second.

He adds that he has three times noticed that animals show alarm immediately before a flash and that in one case a dog walking on grass turned and began to bark angrily in the direction of a very strong flash that came one-fourth second after, striking several of a group of trees 200 yards away. He mentions two occasions when fowls rushed for shelter from the open in alarm before a very near discharge actually took place. In each case the discharge was a very powerful one, taking place on dry soil before rain had fallen. He asks "if it may be that the sensitive feet of the dog could detect vibrations before the discharge took place."

The editors of the magazine answer "that the 'vit' or 'click' accompanying lightning which has struck close by appears to be new; no reference to any similar observation can be found in the literature and at present it is not possible to offer any explanation."

Clicks preceding intense lightning flashes are common at Blue Hill Observatory and undoubtedly can be heard elsewhere under certain conditions, when an insulated metallic conductor is exposed, in a strong electric field, and a grounded conductor is close by. At Blue Hill every intense flash within a radius of 1,000 meters gives this click preceding thunder by an interval which is a function of the distance of the flash. Thus for an interval of 0.4 second (a frequent value), with mean temperature of air column from ground to cloud 1,100 kilograds (303° A. or 86° F.) relative humidity 90 per cent absolute humidity 27 grams per cubic meter of space, wind direction 235° (SW. by S.) velocity 7 meters per second, the distance is

$$\begin{aligned} d &= t\,(V_o\sqrt{T/1000}) + \text{wind} \\ &= 0.4\,(332.11 \text{ x } 1.05) \times 7 \\ &= 142 \text{ meters} \end{aligned}$$

Intervals as large as six seconds indicating a flash distant 2 kilometers or more have been noted.

Regarding the behavior of the dog, it would seem to be not so much a question of sensitive feet as a matter of insulation and increasing electrification to a degree that the hairs, for instance, become discharging points. This bristling can be seen readily on animals caught in thunderstorms near the top of a mountain. I recall being near the summit of Mount Whitney (4,420 meters above sea level, 14,502 feet), during a thunderstorm. The hairs of the burros (pack animals) stood out straight,

and a faint hissing could be heard. A metal button on my cap gave a tingling sensation. I kept wondering how long it would be before a flash of lightning would demolish the entire party of astronomers as they proceeded in close formation to the summit. I think we had a narrow escape from disaster. During a week's stay at the summit we had several thunderstorms, when the lightning seemed to be below us.

The feeling of uneasiness preceding lightning flashes may be due, aside from effects of pressure, temperature, and humidity, to the increasing electrical strain, as a charged cloud comes over the position of the observer. We know from our quadrant-electrometer measurements that at such times the potential gradient increases steadily from 50 volts per meter to 10,000 or more. A jet of water from an insulated collector exhibits many interesting changes as the charged cloud approaches. In fact we can tell just about when the flash will occur. We can also detect and record discharges which an observer fails to detect, if dependent on the eye alone. With each flash there is an instantaneous equalization of potential and return of the needle to zero.

Prof. C. T. R. Wilson has shown (Phil. Trans. A Vol. 221, p. 112, 1921) that continuous currents carried by ions moving in the strong field below the cloud, exist, these ions being produced as a result of point discharges from trees and bushes below the cloud. Prof. B. F. J. Schonland has estimated the magnitude of these currents. (Proc. Roy. Soc. A. Vol. 118, p. 252.)

Using an insulated Acacia Karroo tree, a small thorn tree, about 12 feet high with plenty of thorns, he measured the field and current strength. With a field of negative 16,000 v/m, the current as measured by a unipivot galvanometer with one terminal to tree and other to earth, was 4 microamperes. His table shows that during 230 minutes of strong negative field, the tree discharged 0.0129 coulomb of positive electricity upward, while during 10 minutes of strong positive fields it discharged 0.0001 coulomb of negative electricity. The latter effect was due to a mammatiform cloud residue, the actual storm having receded far away. Confirming previous measurements in 1926, some made in 1927 lead him to estimate the quantity of electricity in an average vertical flash, whether to ground or in the cloud, of 3 kilometers, as 15 coulombs.

We may quote from an earlier paper by the same author, in which the polarity of distant, intermediate, and near-thunder clouds is discussed. We give only intermediate and near storms, although the distances are much greater than where the "click" occurs with the flash. But even at these larger distances it is plain that the increase in the strength of the field is of a progressive character; and hence in case of very near lightning, there might easily be experienced by insulated animals excitation of the fur or hair. Or again the dog may have simply heard the hissing caused by point discharges from the leaves of the tree, which under the conditions given would be excessive. The following particulars have been excerpted from "The polarity of thunderstorms," by B. F. J. Schonland, Proc. Roy. Soc. A Vol. 118, 1928:

*Intermediate storms.*—Figure 6: Storm 25, 24/1/27, 15 h. 7 m. to 15 h. 12.8 m., about 1½ hours after Figure 1.

This is a portion of a record taken on the ball, which had to be lowered to a height of 1 meter above the ground, owing to the negative field of −4,000 v/m prevailing. The following outside observations were made: 7½ m. flash in cloud . . . 8.0 m. double flash to ground at 10.4 kms. . . . 8½ m. flash in cloud . . . storm getting nearer . . . 9¾ m. flash to ground at 5 kms. . . . 10½ m. flash in cloud . . . 12 m. flash in cloud at 5 kms. . . . The storm now came overhead and gave a strong negative field of −5,000 to −10,000 v/m, accompanied by heavy rain, which conveyed a positive charge to the test plate. The record shows 22 positive and 16 negative field changes.

Figure 7: Storm 41, 16/2/27, 16 h. 18 m. to 16 h. 23 m. This record was taken on the ball at the usual height. The storm moved over the station at about 30 kms. per hour. When distant it gave 7 negative and 3 positive field changes. During this record it approached from 11.3 kms. (flash at 18.8 m.) to less than 7 kms. (at 20.8 m.) and at 26¼ m. a flash to ground took place at a distance of 2.8 kms. The field, which was −530 v/m at 21.8 m., increased to −6,000 v/m as the storm came overhead. The field changes at 20.8 m. and 21.4 m. were double, +680 and +1,080 followed by −360 and −760 v/m, respectively, at intervals of about 0.5 second. The record shows 7 positive and 3 negative field changes.

Figure 8: Storm 30, 31/1/27. This record was taken on the ball during the approach of the storm and shows 18 negative and 7 positive sudden field changes. Flashes to ground occurred at 18.4 and 20.4 m., which the record shows to have produced positive changes of field.

The ball was lowered to measure the field at 17.3, 19.6, and 21.4 m. Initially, −109 v/m, the field rose to −420 v/m as the storm approached and later became so strong as to drive the meniscus out of the field of view. At 32 m., after the close of the record, it had reached −10,000 v/m, and the next record, which is shown in Figure 9, was obtained.

A record was made at 17 h. 10 m., when the storm was at a distance of 11 kms., showed that the steady field was then +40 v/m.

*Near storms.*—Figure 9: Storm 30. Test plate, 17 h. 34 m. to 17 h. 44½ m. The distances of 9 of the flashes have been determined from the thunder marks following the field changes and lie between 3 and 6.4 kms. The test plate was uncovered at 34¾ m. and covered for a few seconds at 37, 37¾, 40, and 42½ m., the field varying from −8,800 to −10,600 v/m. The largest sudden change of field, at 35.5 m., amounted to +14,800 v/m and was due to a flash in the cloud at a distance of 4.4 kms. It was followed 3 seconds later by a change of −3,000, v/m. The other negative change, −2,000 v/m, occurred at 39.6 m.

Rain started to fall at 35.5 m., was noted as heavy at 40 m. and as very heavy from 41½ m. to the end of the record. This is the cause of the upward slope of the record, which indicates an average current of $6.5 \times 10^{-14}$ amps./sq. cm. from 34¾ m. to 42½ m. The peculiar hump at 43½ m. is probably due to the heavy rainfall. Flashes to ground occurred at 37.5 m. (5.4 kms.) and 38.8 m. (3.0 kms.). The record shows 34 positive and 2 negative field changes.

Figure 10. Storm 36, 9/2/27. Test plate, 14 h. 6.5 m. to 14 h. 22 m. The distances of 12 of the flashes have been determined and lay between 2 and 7. 2 kms. The test plate was covered for a few seconds at 7, 10, 11.7, 13.6, 15.2 and 19 m., the field varying from −11,800 v/m to −3,500 v/m. The largest sudden change of field amounted to +11,800 v/m and occurred at 9.4 m., momentarily reducing the field to zero.

Three small negative changes of field occurred at 8.7, 11.3, and 1.22 m., the first two being due to discharges at distances of 5.4 and 11.2 kms., respectively. Two larger negative changes occurred at 16.6 m. at the end of a half-minute interval during which a positive field of the order of 6,000 v/m prevailed. They reduced the field by 14,000 v/m in two jumps of −4,700 and −9,300 v/m about 1½ seconds apart.

Rain fell at 12 m., becoming heavy at 13 m., and the upward slope of the record indicates that this was positively charged and have an average current of $4.9 \times 10^{-14}$ amps./sq. cm. between 11.7 and 15.2 m.

The full history of this storm is as follows: At 12 h. 20 m. it was approaching from a distance of 40 kms, and gave 90 negative and 4 positive field-changes. At 13 h. 12 m. it was 6 kms. away and gave rise to a field of −7,000 v/m which rose to −16,000 v/m at 13 h. 41 m. and continued to vary from −8,000 to −12,000 v/m (except for the half-minute of positive field referred to) until 14 h. 27 m. During this half-hour the discharges were between 2.0 and 7.2 kms. off and 72 positive and 5 negative changes were observed. Another record was taken at 14 h. 27 m., just after fig. 10, when the active center was reported to be moving away and the flashes were at distances lying between 7 and 10 kms. This record shows 9 positive field changes followed by 8 negative ones and the sign of the field-changes evidently reversed. The steady field, however, remained between −5,500 and −8,100 v/m for another 31 minutes.

# TEMPERATURE INVERSIONS AT SAN DIEGO, AS DEDUCED FROM AEROGRAPHICAL OBSERVATIONS BY AIRPLANE

By DEAN BLAKE

[Weather Bureau Office, San Diego, Calif., May, 1928]

With the development of apparatus for the exploration of the atmosphere, some of the older conceptions of temperature and wind conditions in the upper air have been altered or greatly modified. It will be recalled that the theory of a constant temperature decrease in the region of the upper air now known as the stratosphere, has been materially changed since Teisserenc de Bort in 1898 carried on his epochal soundings. Wind velocities and directions also have been found to depart materially from the expected, and in the realm of meteorology there is no field more fertile for investigation than that of the upper air.

Since observations were begun by means of airplanes and pilot balloons in San Diego and vicinity, unlooked for temperature and wind variations have been found. Early in the history of aviation, pilots were at a loss to explain the causes of the remarkable temperature inversions encountered aloft, and as the number of pilot balloon soundings increased the existence of unexpected and inexplicable air currents was discovered.

Besides the desirability of improving forecasts for aviation, and widening the scope of our knowledge of aerology, other reasons have prompted the preparation of this paper.

In the first place there has been a specific request for the information it contains. Airplane maneuvers at the naval air station last summer met with such high temperatures at elevations bordering the 1,600 meter level that this year it has been proposed that they be held at a level where the air-cooled motors would not overheat. Again, temperature and humidity are vital factors in the handling of dirigible balloons, and accurate data are necessary. Especially is this true in the vicinity of San Diego, as the Navy Department has begun detailed ground observations in the county for the selection of the most suitable site for the establishment of a base for lighter-than-air craft.

## TOPOGRAPHY AND CLIMATE OF SAN DIEGO COUNTY

San Diego County lies at the extreme southern end of California with Lower California adjoining on the south. To the west the Pacific Coast stretches from the northern to the southern boundary. Except for a narrow strip along the coast, it is rough and mountainous with isolated valleys and mesas of limited extent. The mountains, however, are only moderately high, few peaks rising over 6,000 feet, and their eastern slopes abruptly drop into the desert beyond.

Climatically, the littoral strip is mild and equable with a light rainfall that is confined to the winter season. Its infrequent high temperatures are the product of dynamically heated air currents, and therefore are accompanied by low humidities. The most dominant characteristic is the night and morning strata of "high fog," which persists from May to October with remarkable regularity, and is to be found less frequently during the rest of the year. As this protecting veil extends but a few miles inland, the mountains, mesas, and valleys are much warmer in summer and cooler in winter, with large daily ranges in temperatures most of the year and increasing amounts of precipitation with elevation. Beyond, the great interior valleys have typical desert climates; that is, extremely high temperatures in summer and moderate in winter, and little or no rain at any time.

## AEROGRAPHICAL FLIGHTS AT NAVAL AIR STATION

Observations of temperature, humidity, and pressure in the upper air have been made by airplane at the naval air station on North Island, San Diego Bay, since January 1923. An aero-meteorograph of the Friez type is in use. To keep the data comparable each flight is made along the same general route over San Diego and its environs, and elevation is made slowly so that the elements will have time to become properly adjusted to the changing conditions. The climb is maintained until the temperature decrease becomes regular or the inversion ceases, which is usually between 2,100 and 2,500 meters.

Until January, 1928, the aerograph was carried by the observer in the cockpit of the airplane. At present it is exposed between the upper and lower right wings, and fastened between the two outer struts in such a manner that the vibration is no greater than before the change. In order that an intimation of the variations between the two exposures might be obtained, the writer on May 2 made a flight with the two aerographs used at the air station. These particular records showed a slight time lag in both the hygrograph and the thermograph by the instrument in the cockpit, and a noticeable tendency not to register the extremes. Undoubtedly, the wing exposure, which is away from heat from the engines, is much the best.

All records used in this paper have been made available through the kindness of the commanding officer of the naval air station, Capt. F. R. McCrary; the aerological officer, Lieut. W. K. Berner; and the chief aerographer, A. A. Stotts and the personnel of his office, who have done everything possible to assist in its preparation. The writer wishes to express his appreciation of the many courtesies extended, and the opportunities presented for obtaining first-hand information.

It is unfortunate that a more continuous record could not have been made. There are many reasons why regular observations have not been practicable, the chief being the lack of available airplanes, unfavorable flying conditions, and the closing of the station on Sundays and holidays. To April 1, 1928, 250 aerographical flights were made. Their distribution by years, months, forenoons, and afternoons is shown in Table 1. At present the record is being taken in a regular and systematic

TABLE 1.—*Distribution of aerographic flights*

| | January | February | March | April | May | June | July | August | September | October | November | December | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1923—a. m. | 3 | | | 1 | | | | | | 5 | 2 | | 11 |
| p. m. | | | | 1 | | | | | | | | | 1 |
| 1924—a. m. | 3 | | 1 | | 15 | 6 | 1 | | | | | | 26 |
| p. m. | | | | | | 4 | 19 | 19 | 17 | 13 | 11 | 11 | 94 |
| 1925—a. m. | | | | | | | | | | 2 | 1 | | 3 |
| p. m. | | | | | | | | | | | | | 0 |
| 1926—a. m. | | 9 | 5 | 5 | 2 | 7 | 4 | 4 | | | 5 | 4 | 45 |
| p. m. | | 3 | | | 6 | 1 | | | | | | 1 | 11 |
| 1927—a. m. | 5 | 2 | 6 | 1 | | 2 | | | | | | | 16 |
| p. m. | 1 | 1 | | | | 2 | | | | | | | 4 |
| 1928—a. m. | 8 | 16 | 8 | | | | | | | | | | 32 |
| p. m. | 2 | 1 | 4 | | | | | | | | | | 7 |
| Total: a. m. | 19 | 27 | 20 | 7 | 17 | 15 | 5 | 4 | 0 | 7 | 8 | 4 | 133 |
| p. m. | 3 | 5 | 4 | 1 | 6 | 7 | 19 | 19 | 17 | 13 | 11 | 12 | 117 |

way at 10 a. m., but in the earlier flights no set hour was consistently used. Efforts are made to obtain pilot balloon soundings at or near the time of the aerological "hops," as they are known on the island, so that synchronous wind velocity and direction data are available.

In the summarization of the data, the temperature gradients found aloft have been divided into three classes; those with a regular decrease with increase in elevation, marked inversions, and slight inversions. For convenience of classification, a continuous rise in temperature of more than 5° C. (9° F.) has been arbitrarily designated a marked inversion, and when below this range, a slight inversion. The distribution of the three groups by months is given in Table 2.

TABLE 2.—*Distribution of flights showing marked inversions, slight inversions, and regular decreasing temperatures*

| | January | February | March | April | May | June | July | August | September | October | November | December | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Marked inversions | 1 | 1 | 2 | 1 | 11 | 19 | 22 | 19 | 14 | 5 | 3 | 1 | 99 |
| Slight inversions | 8 | 8 | 7 | 4 | 7 | 2 | 2 | 4 | 3 | 10 | 7 | 5 | 67 |
| Decreasing temperatures | 13 | 23 | 15 | 3 | 5 | 1 | 0 | 0 | 0 | 5 | 9 | 10 | 84 |
| Total | 22 | 32 | 24 | 8 | 23 | 22 | 24 | 23 | 17 | 20 | 19 | 16 | 250 |

Owing to their paucity and lack of continuity, no attempt has been made to segregate the date into forenoon and afternoon readings.

It is at once apparent from the table that the temperature inversions encountered aloft are slight during the winter months and well-marked during the summer months. In fact, every observation from June 1 to October 1, save one, showed an increase at some of the levels.

### CAUSES OF WINTER INVERSIONS

The inversions during the colder months are readily explained by (1) the presence of clear skies and still air causing a net loss of surface heat by radiation; (2) the importation of hot, dry air above the surface layers; (3) the occasional overspreading of the land areas by a stratum of relatively warm, moist air drawn in from the ocean.

The first type cited occurs during periods of clear, cold anticyclonic weather when low temperatures prevail at the surface, due to rapid loss of heat by radiation. Under these conditions a slight increase in temperature sometimes is found as high as 500 meters. Inversions from this source give us in southern California a better understanding why the so-called "frostless belts" and many of our flourishing and unprotected citrus groves are located at elevations between 500 and 1,500 feet.

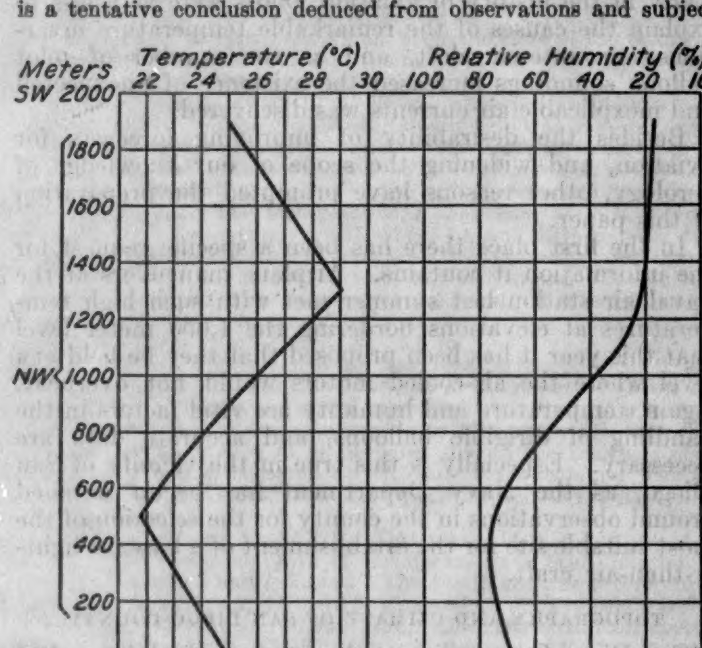
Contrary to expectations, the importation of dynamically heated air appears to be a minor cause of inversions, as it operates only when the warm winds have not reached the surface, which, consequently, is relatively cool. Even then the increases shown are not pronounced, and there is normally little change in temperature to great heights. Air currents of this nature are produced when high pressure overlies the Plateau States, and low barometer is centered over extreme southwestern California or is indicated in the Pacific Ocean off the coast.

Regarding the third type of winter inversions. When the distribution of barometric pressure is such as to cause an indraught of ocean air to overspread the land, a rise in temperature is generally experienced in this layer. For example, the only marked inversion that was recorded in any February occurred on the 25th, in 1927, under these conditions. The aerograph trace sheet on that date showed a steady rise of 7° C. (13° F.), with an accompanying increase in relative humidity of 12 per cent to 500 meters, after which it decreased gradually. Sometimes, however, a decrease is encountered for several hundred meters, which is followed by rising temperature until the top of the strata of ocean air is reached, after which the lapse rate becomes nearly normal.

### SUMMER INVERSIONS AND THEIR CAUSES

But a more complex problem is presented by the inversions encountered during the summer flights. Their very regularity is puzzling. The explanation that has been advanced generally has been expressed by Chief Aerographer J. W. Thomas in the following:[1]

At that season (the summer months) the southwestern semipermanent "Low" is at its greatest intensity and it seems to be the concensus of opinion that the inversion is due to the outflow of heated air from the valleys of the interior * * *. The above is a tentative conclusion deduced from observations and subject




to modification. We have found that although the greater number of pilot balloon soundings made in connection with the aerographic flight do show a layer of wind with an easterly component at practically the same elevation as the inversion, nevertheless there are several records showing an inversion while the pilot balloon ascension made at the same time shows a solid west and northwest wind from the surface to an altitude considerably above that attained in the aerographic flight.

In Figure 1, the temperature lapse rate, the humidity curve, and the prevailing wind directions for every 100 meters up to 2,500 meters, derived from 35 afternoon flights during July and August, 1924, are plotted. As anticipated, the lowest temperatures were reached at the average level of the top of the clouds, the decrease for the first 500 meters averaging 0.6° C. per 100 meters, or 0.4° C. less than the adiabatic rate for dry air. From 500 to 1,250 meters a rise of 7.2° C. is shown, and from 1,250 meters on the temperature fall is at the same rate as the initial decrease, or 0.6° C. for each 100 meters. Surface temperatures corresponded generally with those found at 1,800 or 1,900 meters.

[1] Thomas, J. W.: Aerological work at the naval air station at San Diego. Conference on the Physical Oceanography and Marine Meteorology of the Northeast Pacific and the Climate of the Western Part of the United States (p. 23).

Naturally, the relative humidity and temperature curves parallel each other rather closely but in an inverse sense. With a fall in temperature and a consequent decrease in the capacity of the space for water vapor, the relative humidity would increase until the temperature began to rise, when it would decrease.

Although summer averages aloft are comparable to temperatures reported at stations back from the coast at intermediate elevations, little or no daily similarity exists between the two, and, except in cases of widespread warm waves over the district, temperatures in the free air seem independent of surface conditions either in San Diego County or in the great valleys beyond.

It may be of interest to not that the maximum inversion encountered was 16° C. (29° F.) on August 28 1924, and the highest temperature registered at any elevation was 35.6° C. (96° F.) at an approximate height of 1,300 meters.

There is one relation, however, between the free-air and surface temperatures that stands out prominently, i. e., marked inversions are almost certain to be followed by fog or low clouds every month in the year. This relation, though, is not confined to this locality, but has been found to obtain over other parts of the California littoral. Wright in a study of the fog conditions at Mount Tamalpais observed that[2] "* * * the temperature of the upper air must be higher than that of the lower to produce proper conditions for fog formation," and McAdie in Bulletin L writes that[3] "fogs seem to occur at times of steep inverted gradients."

As no figures showing the percentages of winds from the land and sea at the various levels are available, and no discussion of the subject is complete without them, Table 3 was prepared from the 1 p. m. pilot balloon ascensions during June, July, and August, 1924–1927, the same summer periods covered by the aerological data.

TABLE 3.—*Summary of pilot soundings during June, July, and August, 1924–1927 (in meters)*

| | Surface | 500 | 1,000 | 1,500 | 2,000 | 2,500 | 3,000 | 3,500 | 4,000 | 4,000 | 5,000 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| N | 2 | 5 | 10 | 12 | 11 | 1 | 3 | 4 | 3 | 1 | 1 |
| NE | ------ | 6 | 7 | 7 | 13 | 15 | 10 | 13 | 9 | 9 | 7 |
| E | ------ | 2 | 6 | 12 | 11 | 10 | 11 | 9 | 6 | 3 | 4 |
| SE | 3 | 10 | 40 | 42 | 61 | 56 | 55 | 47 | 48 | 27 | 20 |
| S | 17 | 26 | 37 | 33 | 33 | 32 | 27 | 28 | 26 | 7 | 8 |
| SW | 88 | 85 | 72 | 78 | 82 | 74 | 88 | 80 | 75 | 35 | 25 |
| W | 104 | 39 | 21 | 26 | 27 | 21 | 23 | 21 | 12 | 9 | 3 |
| NW | 130 | 163 | 123 | 95 | 46 | 22 | 13 | 14 | 18 | 12 | 12 |
| Calm | ------ | ---- | 2 | 1 | 1 | ------ | ------ | 1 | 2 | ------ | ---- |
| Total | 344 | 330 | 318 | 306 | 285 | 231 | 230 | 217 | 199 | 103 | 80 |
| Sea, per cent | 99 | 93 | 80 | 77 | 66 | 65 | 66 | 67 | 67 | 61 | 60 |
| Land, per cent | 1 | 7 | 20 | 23 | 34 | 35 | 34 | 33 | 33 | 39 | 40 |

| | 6,000 | 7,000 | 8,000 | 9,000 | 10,000 | 11,000 | 12,000 | 13,000 | 14,000 | 15,000 | 16,000 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| N | 1 | ------ | ------ | 1 | 1 | ------ | ------ | ------ | ------ | ------ | ------ |
| NE | 4 | 2 | 1 | 1 | ------ | ------ | ------ | ------ | ------ | ------ | ------ |
| E | 4 | 2 | 2 | 1 | ------ | ------ | ------ | ------ | ------ | ------ | ------ |
| SE | 12 | 6 | 2 | 2 | 2 | 2 | 1 | 1 | ------ | ------ | ------ |
| S | 5 | ------ | 1 | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ |
| SW | 19 | 7 | 5 | 3 | 4 | 4 | 4 | 3 | 1 | 1 | 1 |
| W | 3 | 2 | 3 | 1 | ------ | ------ | 1 | ------ | ------ | ------ | ------ |
| NW | 6 | 4 | 2 | 1 | 1 | 2 | 1 | 1 | ------ | ------ | ------ |
| Total | 54 | 23 | 16 | 10 | 8 | 8 | 7 | 5 | 1 | 1 | 1 |
| Sea, per cent | 61 | 57 | 69 | 50 | 62 | 75 | 86 | 80 | 100 | 100 | 100 |
| Land, per cent | 39 | 43 | 31 | 50 | 38 | 25 | 14 | 20 | 0 | 0 | 0 |

Even the most cursory examination forces us to draw several obvious conclusions, namely: (*a*) That at virtually every level, winds were from the ocean the larger percentage of the time; (*b*) that between 2,000 and 10,000 meters the percentages from the land and ocean remained fairly constant; (*c*) that beyond 10,000 meters the few soundings obtainable showed an increasing frequency from the ocean; (*d*) that the prevailing direction at all levels was southwest; (*e*) that the northwest currents believed to predominate at the higher elevations, summer as well as winter, were not in evidence.

Although a chart has not been prepared for velocities during the same period, it was further observed that at the soundings under 2,500 meters they were rarely other than light, and when from the eastern or land quarter were more in the nature of a drift than a current.

If we can make our deductions from four year's record, then there must be other causes for the steep inverted gradients besides an overflow of hot air to the coast from convectional action in the Imperial and Colorado Valleys, as inversions occurred at every observation regardless of wind direction.

Hot weather in southern California, in summer as well as in the other seasons, is almost always caused by dynamically heated winds that have their origin in anticyclonic areas over the Plateau States. A relationship between easterly winds at high elevations at Los Angeles and unusually high surface temperatures on the following day has occasionally been noted and referred to in several of the monthly free-air summaries. (See Aerological Observations, Monthly Weather Review, p. 244, May, 1927.) Occasionally, when the pressure gradients are unusually steep, these winds extend to the ocean, but normally the sea breeze modifies the temperature near the coast.

When such pressure conditions prevail, winds are from the eastern quadrant at most levels irrespective of the surface direction. Thus there appears to be a circulation between land and sea which has been confused with the daily land and sea breeze that is so prevalent in many regions. In summer no well-defined interchange has been discovered, but, as Hann expresses it:[4]

> The sea breeze upon the coast of southern California is, however, a wind which partakes rather of the character of the monsoon, because it is an effect of the prevailingly higher temperature in the interior of California as compared with the ocean.

Hann's contention is further proved by the fact that all mountain stations show prevailing winds from the west during the warmer months of the year.

It is highly probable that air movement from the east is given impetus at times by currents originating in the desert regions, but the generally accepted idea that convection is the cause of winds, from that direction is not tenable.

Littoral California enjoys its remarkably cool summer climate because of its proximity to the ocean. As the inland regions become heated an indraught of cool, moist air sets in which is maintained all summer. Considerable cloudiness results that further screens the land from the sun, and it does this so well that the mean temperatures are lower than any in the entire State, except those reported from the highest elevations. A distance of only a few miles from the shore line makes a great difference, and we find monthly averages between 10 and 20 degrees higher at stations a dozen or so miles inland.

There are reasons for believing that this stratum is wedge shaped, deepest over the ocean and thinning out over the land. Optical haze, due to sharply defined temperature layers, and the observations of aviators seem to justify such a conclusion.

Unquestionably, then, the explanation of the inversion lies in the presence of an abnormally cold stratum at and

[2] Wright, Herbert H. Fog in Relation to Wind Direction on Mount Tamalpais, Calif., Monthly Weather Review, vol. 44, pp. 342-344.
[3] McAdie, Alexander G., Climatology of California, Bull. L., pp. 241.

[4] Hann, J. Handbook of Climatology, translated by R. De C. Ward, pp. 156-157.

immediately above the surface extending to about 800 meters, and not in an anomalous air current aloft. Wyatt and Lawing have stated that inversions were not encountered in the few aerological trips they made over the ocean and the Imperial Valley.[5] This is in accordance with my conclusions; they should be found only over the narrow strip paralleling the coast.

### CONCLUSIONS

Temperatures aloft in other than the summer months normally decrease with elevation, or, occasionally, there is a small inversion from one of three causes—radiation and conduction in the layers just above the ground; importation of warm, dry air; or an indraft of relatively warm, moist air from the ocean.

Inversions during the summer are of regular occurrence, usually following a drop in temperature from the surface to 500 meters. The highest temperatures occur near the 1,250-meter level, where they average about 4° C. higher than at the surface, and temperatures comparable to those at the surface are reached at 1,800 or 1,900 meters.

That the summer inversions are not caused by an overflow from ascending air currents in the desert valleys to the east is evident. Prevailing wind directions at all heights are from the ocean. Occasionally a drift from the east is observed when temperatures in the interior are unusually high, but as these high temperatures are caused by anticyclones over the Plateau States, then the winds from this direction are also the result of this same pressure distribution.

As already stated there is a stratum of relatively cool air of oceanic origin over the littoral districts. This stratum is overtopped by warmer air of continental origin that slowly drifts oceanward in the hot season. These conditions are brought about by the broader relations of marine and continental climates and may be found in their fullest development in the border zone between the two climates.

### DISCUSSION

Chairman Lastreto felt the paper was too technical for a layman like himself to discuss, though he confessed to a deep emotion at the ability with which many old theories had been blasted.

Mr. Gordon wondered where the rising hot air goes from Yuma; it goes up and should come down somewhere, but where?

Mr. Blake stated that Sonora storms are caused by a meeting of the sea and land winds over the mountains; but just how far westward the convectional currents out of the Imperial Valley extend is unknown and is a problem that needs study.

Mr. Gordon said there should be currents aloft out of the valley in practically all directions.

Mr. Blake replied that strong convection over the valley had not been experienced by flyers whom he had interviewed. No extreme bumpiness was reported at the elevations where it is usually found.

Mr. Young asked if different directions of wind were found at different times of the day from the various pilot-balloon observations, to which Mr. Blake replied that while he used the 1 p. m. observations, the aerographers at North Island believed that there was little difference during the 24 hours. Nocturnal data, however, were not available and therefore the answer was in doubt.

Major Bowie explained that by means of numerous pilot-balloon reports received in the San Francisco office from stations in the southwestern quarter of the United States it is a simple matter to construct the isobars for various elevations up to 4 or 5 kilometers. Thus the changes in wind direction at various levels, ranging from an inflowing circulation at the surface to an outflowing circulation aloft, indicate that as we strip off the isobaric surfaces over the interior, one by one, the LOW at the surface gradually gives way to a HIGH in the upper air.

At the higher elevations the barometric gradient is actually outward instead of inward. We are in such a case dealing with a theoretical thermal cyclone as described by Ferrell. The explanation of the wind circulation aloft at San Diego is very easy, it seems to me; the air is moving in a wide circle, and while it may originate in the region to the southward of the Imperial Valley it passes seaward in a circuitous route aloft, and when observed at San Diego is moving in a clockwise direction, because at high levels it constitutes the outflow of air from the anticyclone capping the low-pressure area, which exists only in the lowest atmospheric strata.

[5] Lieut. B. H. Wyatt and M. R. Lawing. Discussion of Papers in Bulletin Am. Metl. Society, Nov., 1925. Pp. 154-157.

## THE MEASUREMENT OF SKY COLORING

By FRANZ LINKE

[Frankfort on the Main, Germany]

In the year 1922 I approached Prof. W. Ostwald, of Grossbothen, with a request for the making in his laboratory of a technical, well-defined, and certainly reproducible blue scale for the estimation of the color of the sky. With a well-known obliging interest in all applications of his color lore Professor Ostwald undertook the task and put at my disposal a rather large number of copies of a blue scale in seven parts, which showed logarithmic transitions from pure white to ultramarine blue. I then numbered the pure white 0 and the ultramarine 14, so that the even numbers indicated the several color steps of the scale and the odd numbers interpolations. Since that time the scale has been employed at many places for the estimation of the coloring of the sky. Professor Ostwald himself reports on the color-technical principles of this blue scale, so that I have only to make statements on the method and purpose of the observations and the results to date.

*Method of observation.*—The observer places himself with his back to the sun and observes for at least 30 seconds the bluest point in the sky, which is 70° to 90° distant from the sun in the direction of its meridian. Without removing his eyes from the sky the observer arbitrarily opens the scale at a tone and quickly brings it into the range of the eye so that it comes into the light of the sun. After some practice, even when the exact coloring of the sky does not contain white and blue only, the observer forms an opinion whether the blue tone of the scale is lighter or deeper as compared with the blue of the sky. The scale made up in book form is then turned until the observer either finds a color tone in sufficient agreement with the coloring of the sky or is

convinced that the blue coloring of the sky lies between two successive tones of the scale. Some practice and willingness are necessary especially when—as often happens—there are present in the sky green, red, or black tones in addition to white and blue. The observer soon becomes accustomed to focus the sense of sight on the blue coloring and eventually to pay no attention to the secondary tones. Only at great heights, either in aircraft or on a high mountain, is the blue of the sky so mixed with black that there are noticeable differences relative to the color scale made up of blue and white alone. Here it is necessary that the estimation of the blueness be made always by the same observer or that several observers practice one after another. If the observer holds the blue scale in the shade and looks quickly from the color scale to the darkest part of the sky and then back, then on an average he will estimate two or three shades lower, a result of the fact that the color tones of the scale are dependent on the amount of illumination.

It is sufficient to carry out such observations two or three times daily at determined hours, and of course most practicably at the international hours, 7 or 8 a. m., noon to 2 p. m., and about 7 p. m. (at least in the summer). In winter a 10-hour period is to be recommended. In the statistical enumeration there is noted how often in a given month the different scale values were found, that is in percentage of the total number of observations. Since the full number of observations, two or three, will not be available on all days a single value for each day determined by averaging must be considered in monthly means or the calculation must be made for each observation hour.

*Results of observation.*—Unfortunately, data on the coloring of the sky for a long period of years are not available. On the basis of my Argentine series (1923) I was first able to state that the blue coloring of the sky (B) stands in logarithmic relation to the turbidity factor (T). There exists the following relation, $B = 12.0 - 14.5 \log. T$. On our Lapland expedition (1927) I ascertained that polar air has a deeper (blue) coloring than sea or tropical air. Before approaching cloudiness there occurs a marked decrease in blue coloring, thus a lighting up of the sky, caused by hydroscopic enlargement in the aerosole (dispersed particles suspended in the atmospheric gases).

Never could there be recognized a daily period in blue coloring, although it must be assumed as certain that the darkest point of the sky is darker, taken absolutely, when the sun is low than when it is high. But since the blue scale is evidently made lighter in equal measure through illumination by the sun, this effect is canceled, so that with this blue scale one arrives at an estimate that is independent of the sun. F. Loewe found in his aircraft flights an increase in blue coloring from 6.4 at the ground to 11.8 at the elevation of 6km. (0–14 scale).

The *purpose* of this estimation of the blue coloring of the sky is a rough approximation of the purity of the air; that is, of the number and size of the aerosole. Heretofore there have been in use in widely different parts of the earth over 100 scales of blue. It is to be desired that results of observations be made known from time to time; with careful observance of the above directions these will serve as comparable data.

*Sets of the blue scale.*—The Meteorologisch-Geophysikalische Institute, Frankfort on the Main, receives the scales in rather large orders from the laboratory of Professor Ostwald, and forwards them in return for the manufacturing cost of 3.5 marks plus postage.—*Translated by W. W. Reed.*

## BLUE-SKY MEASUREMENTS AT WASHINGTON, D. C.

By IRVING F. HAND

[Weather Bureau, Washington, July 31, 1928]

The method of obtaining and utilizing blue-sky measurements has been described in the above article by F. Linke. Since the publication of my brief note on "Blue-sky measurements" in the MONTHLY WEATHER REVIEW for May, 1927, no skies of a deeper blue than 8, or of a whiter color than 4 have been observed. A summary of all observations to date is given in Table 1.

Visibility and polarization show the greatest correlation with sky color. However, due to topography and other reasons, such as low haze, fog in the valley, poor illumination owing to position of the sun, cloud arrangement, etc., it often happens that the visibility is relatively poor with a deep-blue sky; an effect which is masked in the table by the large number of observations. Polarization is less affected by such causes, however, as these measurements are generally made in the same sector of the sky as the color measurements, or to be more exact, at a point 90° from the sun and in his vertical, with a solar altitude of 30° (air mass = 2.0). It is thus evident that when observing the sky for color at a comparatively high angle less interference due to atmospheric pollution or to optical phenomena will occur than when measuring visiblity through a layer of the lower air 50 or more miles in extent.

TABLE 1.—*Relation between sky color and other meteorological elements*

| Color scale | Visibility | Skylight polarization | Solar radiation at normal incidence. Air mass = 2.0 | Number of dust particles per cubic centimeter | Vapor pressure | Wind | Average number of days since precipitation occurred |
|---|---|---|---|---|---|---|---|
| | *Miles* | *Per cent* | *Gr. cal./cm.²* | | *Inch* | *M. p. h.* | |
| 4 | 14.9 | 52.6 | 1.05 | 911 | .702 | 4.3 | 2.4 |
| 5 | 23.3 | 56.5 | 1.12 | 702 | .697 | 5.4 | 1.8 |
| 6 | 37.8 | 59.0 | 1.18 | 521 | .520 | 8.4 | 2.3 |
| 7 | 44.4 | 61.1 | 1.25 | 811 | .382 | 10.7 | 1.3 |
| 8 | 50.0 | 63.0 | 1.37 | 100 | .100 | 30.0 | [1] 0.0 |

[1] Immediately following rain.

The irregular relationship between sky color and the number of dust particles in the atmosphere is due to the location of the observatory in a suburb of Washington, as an easterly component of wind will give dust-count values of city conditions, while a westerly component will give country values. It was found that by eliminating a small number of observations taken with a deep-blue sky in which the wind was from the east and the number of dust particles several hundred per cent over normal, the

relationship between sky color and number of dust particles became quite close.

Studies of the dust content of the atmosphere [1] have shown that there is a decided correlation between atmospheric dust content and wind velocity, as the higher velocities tend to carry away impurities. Thus the apparent close relation between sky color and wind velocities is in reality but a secondary effect.

As would be expected, the amount of water vapor in the atmosphere has a strong influence on the color of the sky. Generally speaking, it has been found that the clearest or the bluest skies occur shortly after precipitation.

The correlation between sky color and radiation intensity is so close that it is nearly always possible to estimate with a surprisingly high degree of accuracy the value of the latter element by merely looking at the sky.

[1] Kimball, Herbert H. & Hand, Irving F. Investigations of the dust content of the atmosphere. Mo. Wea. Rev., Mar. 1924, 52:133-141.; Kimball, Herbert H. & Hand, Irving F. Investigation of the dust content of the atmosphere. Mo. Wea. Rev., June, 1925, 53:243-246.

## HEAVY SNOWFALL OF APRIL 27 AND 28, 1928, IN UPPER OHIO VALLEY

By W. C. Devereaux

[Weather Bureau, Cincinnati, Ohio]

One of the greatest snowfalls of record, not only for April, but for all months, occurred on April 27 and 28, 1928, in extreme eastern Kentucky, the mountains of North Carolina, portions of West Virginia, and southwestern Pennsylvania. This snowfall was unusual as it occurred in the extreme northwestern section of a general low area moving northeastward over the South Atlantic States, when the season was far advanced, and over a region much of which is comparatively free of heavy snowfalls.

The area of heavy snowfall extended from Asheville, N. C., to west-central Pennsylvania, a distance of 400 miles. Within this region the surface of the ground varies mostly from 1,000 to 3,000 feet above sea level. With the exception of Mount Mitchell in North Carolina at an elevation of over 6,700 feet, the highest hills or so-called mountains do not exceed 3,000 feet in elevation, with a few exceptions in West Virginia. Although the differences in elevation between the valleys and the hilltops do not exceed a few hundred feet, the difference was sufficient to give snow on the hills and mostly rain in the valleys.

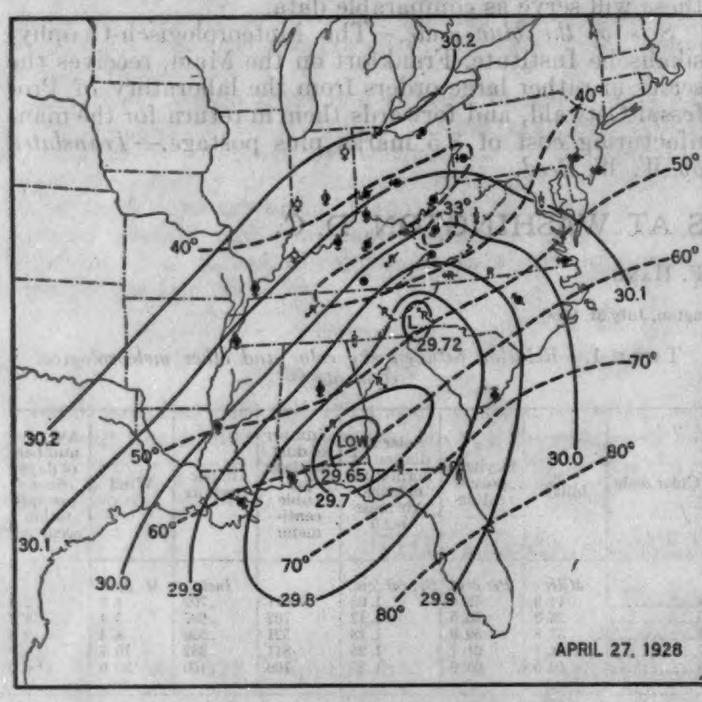



Fig. 1.—Weather map 8 a. m., 1928. For detailed data see Figure 2

There was but little indication of heavy snow for West Virginia on the Daily Weather Map for 8 a. m. April 27. (See fig. 1.) At that time the general storm area was central over southern Alabama and moving northeastward. Snow was falling at the time of observation at Elkins, W. Va., and the wind was southeast at Asheville, N. C., which might be considered irregular, but otherwise nothing unusual was shown on the map.

Another map on a much larger scale, and for the Ohio Valley only, was prepared at the same time at the Cincinnati station. (Fig. 2.) Weather reports from river stations, in addition to the regular reports, were used in the preparation of this map. While the reports from the substations do not show atmospheric pressure the other weather elements can be used to advantage.

This special map shows a decided northward bulge of the barometric lines over the upper Ohio Valley, with a secondary depression fairly well defined over extreme western North Carolina, the center being near to and just west of Asheville at 8 a. m.

The special map shows that the isobars are crowded comparatively close together from eastern Tennessee to West Virginia, and heavy rain and snow started early that day in eastern Kentucky and all of West Virginia. Up to the time of observation more than an inch of precipitation had occurred along the Kentucky-Virginia line and at one station in West Virginia. This rapid development of an extensive area of precipitation was a good indication of the strength of the storm.

A careful study of all the data shows the development and growth of this slight secondary depression over the Tennessee-North Carolina line. The pressure began to fall at all the surrounding stations about 2 a. m. April 27, and rain started about the same time in extreme eastern Tennessee and extreme western North Carolina. The wind at Asheville was south from 2 a. m. to 4 a. m., southeast from 4 a. m. to 9 a. m. and north or northwest after 9 a. m. At Wytheville, Va., the wind was northeast from 2 a. m. to 4 a. m., east from 4 a. m. to 1 p. m., and then shifted to north and northwest.

Another special map for 12 noon, prepared later from mail reports, is reproduced as Figure 3. This map shows the northward bulge in the pressure lines,[1] and that the secondary depression was moving slowly northeastward and filling up. The wind shift and pressure changes indicate that the secondary depression passed Asheville about 9 a. m., Wytheville, Va., about 1 p. m., and merged with the general storm area during the afternoon of April 27. More important than pressure or wind elements on the noon map are the lines that show the time of beginning of precipitation. This is an element that should be shown on forecast maps. The northern bulge in the pressure lines disappeared during the afternoon of April 27 over the extreme eastern edge of the Ohio Valley. The wind at Pittsburgh, Pa., shifted from northeast to

[1] See figs. 1 and 2 for pressure lines.—Ed.

east at 10 a. m., and continued in that direction until 3 p. m., when it backed to northeast and later to north. The general drift of air from the Atlantic during the day of heaviest snowfall was to the west across Pennsylvania, then to the south across Ohio and to the southeast over West Virginia where another current was encountered from the Middle Atlantic coast. The meeting and mixing of these two currents appear to have been the cause of the heavy snowfall.

southwestern part of the State also. The heavy snow and the high wind together caused great damage to telephone and telegraph lines, the poles being broken by the hundreds east, south, and southeast of Pittsburgh. The State highway department (Sunday, 29th) reported roads blocked by snow in these districts, and advised only necessary traffic on other roads which were open but still in poor shape for heavy traffic. At Somerset, in Somerset County, 36 inches snow was reported on the

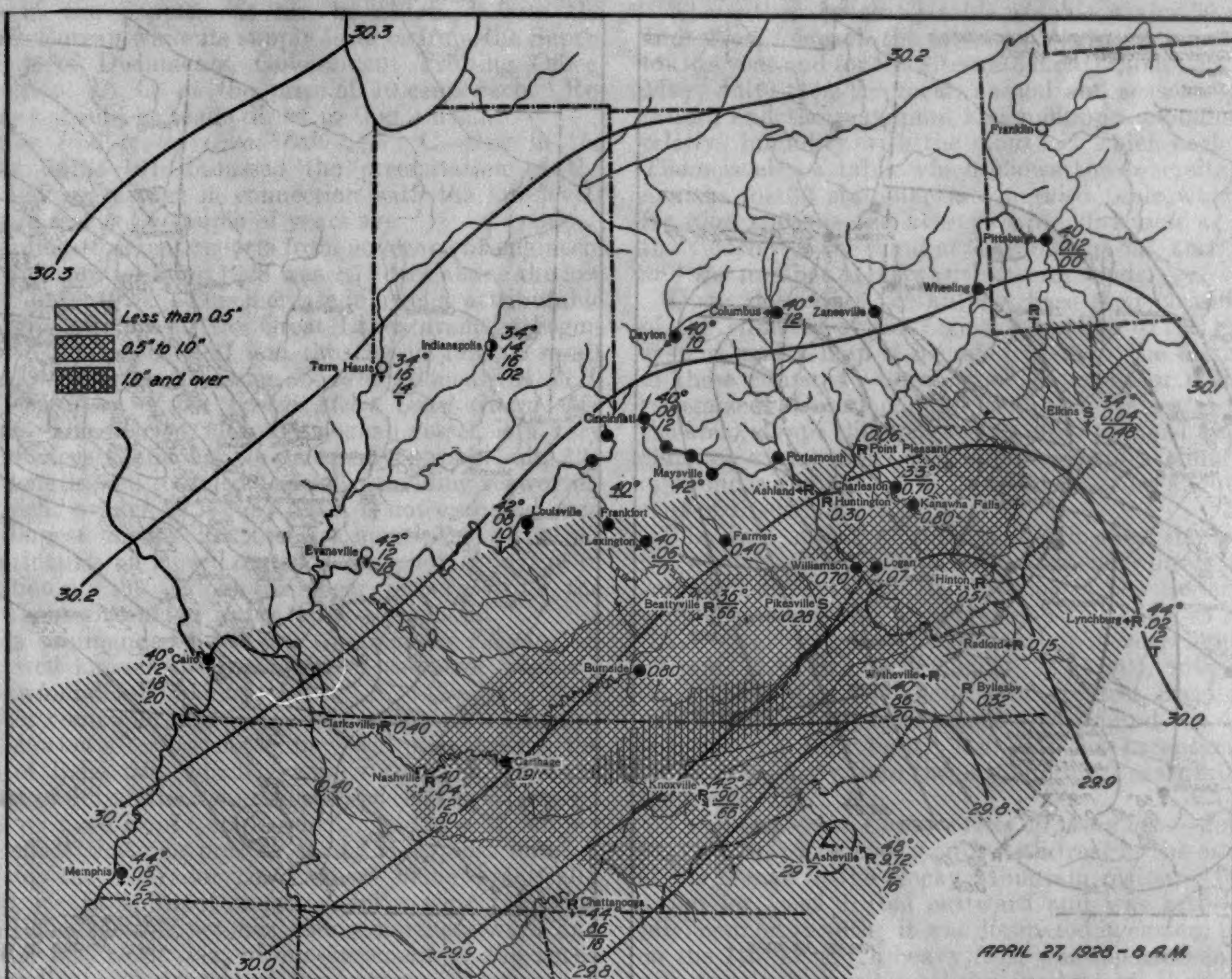



FIG. 2.—Weather map same date as Figure 1 but on a larger base; the map includes detailed data of temperature and precipitation at river stations in Ohio drainage, also temperature, pressure, wind velocity, and precipitation in order named at Weather Bureau stations

Figure 4 shows the total precipitation and the total snowfall for April 27 and 28, 1928. The precipitation is the upper figure and the snowfall the lower figure. One station in West Virginia reported 40 inches of snowfall, several reported 30 inches or more, and 20 inches or more covered nearly one-half of the State. The largest amounts reported in other States were as follows: 36 inches in Pennsylvania, 15.5 inches in Kentucky, 14 inches in Virginia, and 13 inches in North Carolina.

The following extracts are brief descriptions of the heavy snowfall:

By WILLIAM S. BROTZMAN

[Weather Bureau, Pittsburgh, Pa.]

This is the worst snowstorm ever experienced in Pittsburgh so late in the year, and probably the worst for the ground; at Sand Patch, in same county, between 17 and 18 inches. Very little up the Allegheny, and still less west of Pittsburgh.

By HARRIS A. JONES

[Weather Bureau, Elkins, W. Va.]

The big snowstorm of April 27 and 28, 1928, was certainly a record breaker for April, and lacks but one of being the greatest in the history of the Elkins Weather Bureau station, 30 years record. On April 8, 1902, there was a snowfall of 16 inches, with a maximum depth of 16 inches. November 9, 1913, we had a snowfall of 18 inches, with a maximum depth on the 10th of 20 inches.

The snow started here shortly after midnight a. m. of the 27th, but it was so warm that only on the sod and on roofs did it accumulate until about mid-forenoon. By noon of the 27th we had about two inches of very wet

snow. After that it piled up slowly, considering the amount of water content of the snow. Being wet and barely freezing, with practically calm air, it stuck to the branches of trees and to wires—in fact to everything that was exposed. Traffic on the roads was almost completely blocked. Train schedules were badly disarranged. Communication by wire was completely demoralized for two days. The newspaper here got Associated Press news over the radio. Many trees were badly broken. One farmer living in the outskirts measured carefully and gave me a report of 19 inches at his place. A mountain man said that he measured it at various places on the mountain and it was anywhere from 2 to 3 feet deep. One report said that it was 38 inches deep at Glady, a mountain town about 10 miles southwest of here. There was no damage to the fruit buds by the coating of snow and soft ice, though there was considerable damage to the fruit trees.

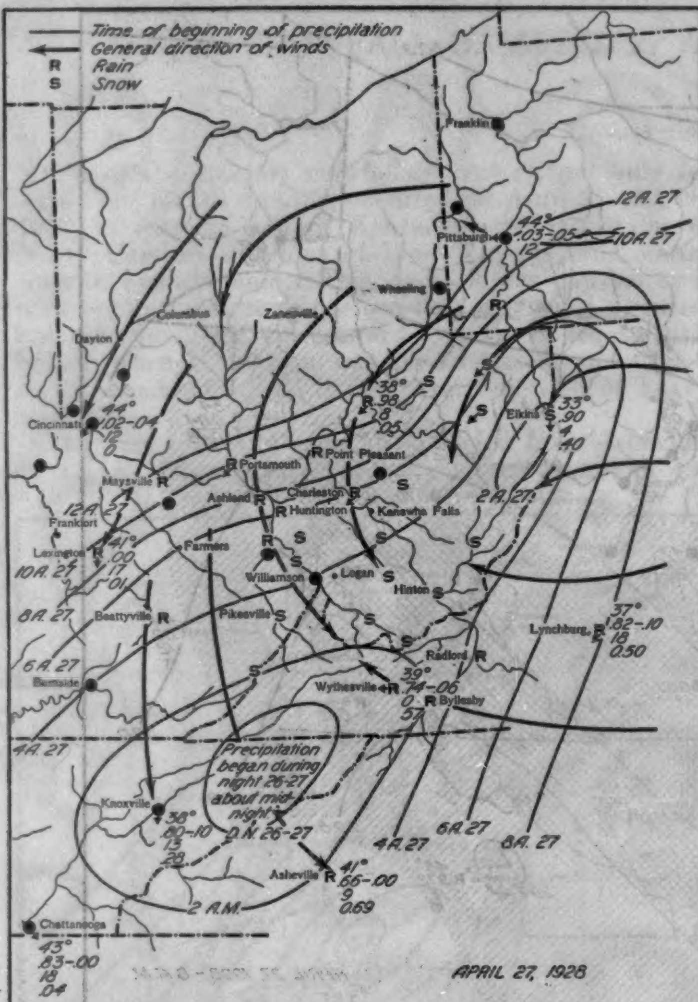



FIG. 3.—Time of beginning of precipitation between midnight April 26 and noon April 27

By APPALACHIAN POWER Co

[Bluefield, W. Va.]

Beginning with a light misty rain about 9 o'clock on the morning of April 27, in the immediate vicinity of Bluefield, we had a general mixture of rain, sleet, and snow throughout the 27th and the 28th of April and the combined result amounted to 2 inches of water in the gauge. Roughly, I would suppose that at least 1 inch of the above amount was rain and the remainder sleet and snow.

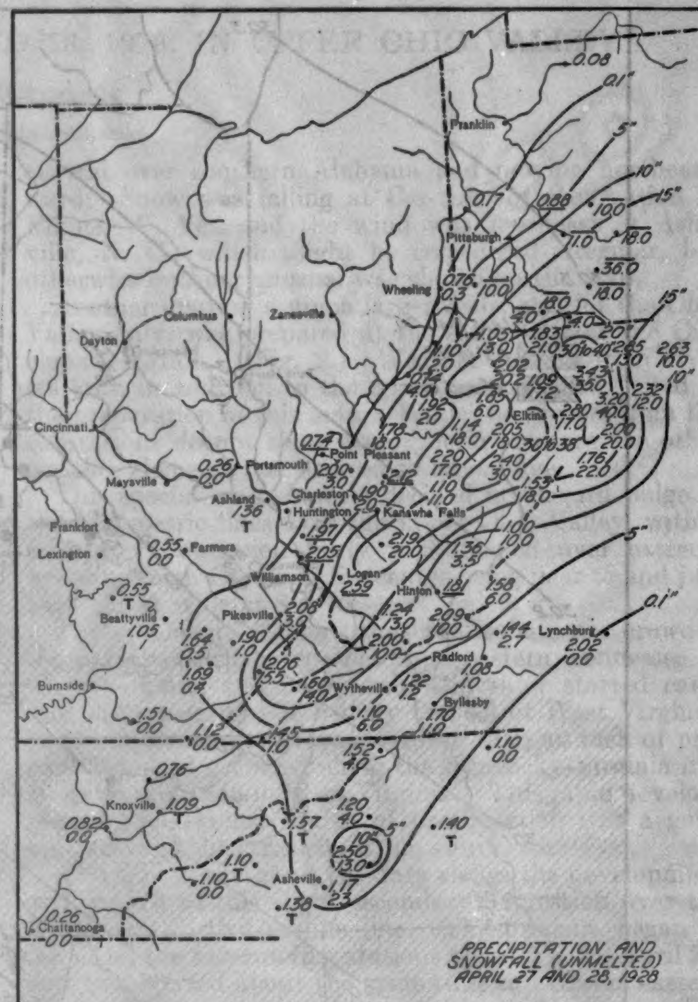



FIG. 4.—Total depth of rain and unmelted snow April 27–28. Top figures, total rain plus water equivalent of any snow that may have melted; bottom, total depth of unmelted snow in inches

We have no reports from other stations outside of Bluefield. The original Appalachian Power Co. system which covers approximately 30 counties in southern Virginia and West Virginia, suffered but little as a result of this storm. I understand, however, that our Charleston, W. Va., and Logan, W. Va., districts did suffer considerable damage. Our records indicate that the storm did not extend far east of Bluefield, W. Va.

## NOTES, ABSTRACTS AND REVIEWS

*Monthly Weather Review Supplement No. 31.*[1]—Mr. Reed continuing his previous work, as noted in this REVIEW 55:132, now presents one more installment of climatological data this time for Tropical South America, excepting Brazil. Detailed data of temperature and rainfall, so far as available are presented for the three Guianas, Venezuela, Colombia, Ecuador, Peru, and Bolivia with a brief discussion of the climate of each. Copies of the Supplement can be obtained from the Weather Bureau while its supply lasts or from the Superintendent of Documents, Government Printing Office, Washington, D. C. at the price of 10 cents each. Remittances should be made direct to that official.

*Rise in level of the Great Lakes.*—P. C. Day in the REVIEW 54:85-101 discussed the precipitation of the Great Lakes drainage in connection with the low levels that were reached a couple of years ago.

According to recent reports from government engineers Lake Michigan for June 1928 was 1.71 feet above the low stage of June, 1926. This increase in level is attributable to the precipitation in the Great Lakes drainage beginning with the fall of 1927 and thus far in 1928, a result foreshadowed in the discussion above mentioned.—*A. J. H.*

*The expedition of the United States Coast Guard ship Marion.*—The *Marion*, although a small vessel, is a very seaworthy craft; she has an unusually strong hull, 125 feet in length, well rounded and full, providing seaworthiness which, strange as it may seem, is not exceeded even in the largest liners. For the last month or so she has been outfitting at New London, Conn., for a voyage of exploration in the waters that bear icebergs from the region about Greenland to the Grand Banks.

She is commanded by Lieut. Commander Edward H. Smith, well known for researches in ice-patrol work off the Newfoundland banks. Lieut. N. G. Rickets is second in command and the crew consists of 20 men.

The *Marion* after leaving Sidney will pass through the Straits of Belle Isle, which generally are open from the first part of July until the middle of December. Reports already received from Commander Donald MacMillan are to the effect that the present season is a most unusual one along the Labrador coast, there being practically no field ice in spite of much easterly wind. Having passed Belle Isle will set her course northeastward and begin the real work, viz, of measurement of the speed and direction and depths of the currents encountered, the making of meteorological and oceanographic observations, and the detailed observations of icebergs. The main object of the expedition is to make a systematic survey of waters that bear icebergs to the Grand Banks, thereby adding to the stock of knowledge of this inhospitable region.—*Excerpted from mimeographed report by U. S. S. Marion.*

*The vagaries of June, 1928, weather.*—The weather of the current June in Washington, D. C., and elsewhere in northeastern United States, was characterized by an unusually large number of days with a trace or more of rain, 23, and the number of days with 0.01 inch or more was 18, a number that equals the greatest number in any June during the last fifty-odd years. Notwithstanding the large number of days with rain the total rainfall of the month was but 2.26 inches or 1.47 inches below the normal. Naturally cloudiness was greater than usual, the day temperatures not so high as in normal June weather and a cool and rather dry month was experienced—*A. J. H.*

*The climate of Russian middle Asia.*—Under the title of "The Climate of Russian Middle Asia"[2] by W. Koeppen and R. Geiger, there has appeared a brief discussion of the climates of Russian Turkestan, a region extending roughly from 36° to 48° N. latitude and from 52° to 82° E. longitude.

The authors present a table which contains 50 stations and gives, for each the altitude, the mean temperatures for the year and for the alternate months, January, March, May, July, etc., the mean annual and seasonal precipitation, and the maximum and minimum cloudiness and relative humidity with the month in which each occurs. There is also a table which shows the precipitation by months for 32 stations; and a third table which gives for nine stations the average wind direction as well as the velocity of the wind at 7 a. m., 1 p. m., and 9 p. m., and the number of days with strong winds.

Upon these data the authors base their classifications of the climates of the region according to the Koeppen system, and a map is included to show the distribution of these climates. Seven main divisions or regions are recognized: Desert climate (which comprises about half the area), steppe climate, estesian climate, moist temperate climate, winter-moist-cold climate, tundra climate, and dry tundra climate. The last four make up about 10 per cent of the whole area.

The data, map, and discussion bring out the fact that the whole region is one of relatively cold winters and hot summers, except at high altitudes in the eastern part, where the mean July temperature falls as low as 13.6° C. (56.5° F.). In general, the rainfall is very light, from 59 mm. (2.36 in.) to 576 mm. (23.04 in.), with March, April, and May the months of greatest precipitation. The winds, except for a small area around the Caspian Sea, are uniformly light; and, with few exceptions, they blow prevailingly from the east and northeast throughout the year.—*C. E. K.*

*June weather in United States 50 years ago.*—June, like May, 1878, was a cool month with frost in the early part of the month in the Rocky Mountain region. The condition for frost drifted eastward and was across upper Michigan on the 6th; it was dissipated in eastern districts on the 7th, although heavy frost was reported as having occurred in exposed localities in western Pennsylvania on the 6th. In general the month was without distinctive features.—*A. J. H.*

## METEOROLOGICAL SUMMARY FOR SOUTHERN SOUTH AMERICA, MAY, 1928

By J. BUSTOS NAVARETTE

[Observatorio del Salto, Santiago, Chile]

The most important anticyclones, all of which moved from Chiloe toward northern Argentina, were charted during the following periods: 2d to 4th, 9th to 12th, and 14th to 19th. The last two brought settled weather and moderate temperature during practically all of the second decade.

Following the depression of the 8th, which caused rain in all of the central and southern region, there was no important cyclonic activity until the 20th, when a marked period of unsettled weather began.

[1] Reed, W. W. Climatological data for northern and western tropical South America. pp. 21, price 10c.

[2] Das Klima von Russisch-Mittelasien, Sonderabdruck aus Petermanns Geographischen Mitteilungen 1927, Heft 9/10.

The depression of the 20th–21st was attended by general rainfall from Aconcagua to Chiloe. The greatest 24-hour amounts in inches were 1.65 at Talca, 1.46 at Valparaiso and San Fernando, and 1.22 at Curico.

On the 24th there appeared a center of low pressure which remained stationary off Isla Mocha until the 28th, bringing continued unsettled weather and rain. The heaviest daily amounts of precipitation in inches were 1.34 at Talca, 1.50 at Valdivia, 2.01 at Cauquenes on the 25th, and 2.20 at Temuco on the 27th.

Lastly, on the 29th–30th there was a depression off the middle coast accompanied by rainfall from Coquimbo to Chiloe, the heaviest falls being recorded on the 29th—Valdivia, 2.24 inches, and San Fernando, 2.28 inches.

The region receiving rain during the month extended from Coquimbo to Magallanes. The total precipitation for the month was 3.87 inches at Santiago and 9.79 inches at Valdivia.—*Translated by W. W. Reed.*

## METEOROLOGICAL SUMMARY FOR BRAZIL, MAY, 1928

By FRANCISCO DE SOUZA, Acting Director

[Directoria de Meteorologia, Rio de Janeiro]

In May seven anticyclones were charted; some of these were of rather marked intensity and caused decided fall in temperature in the south. The weather was unsettled and at times stormy, especially on the southern coast, where occasional tempestuous winds occurred. Precipitation was light in the northern and central regions, the monthly totals showing deficiencies of 3.03 and 1.30 inches, respectively. In the southern region very irregularly distributed rainfall gave an average excess of 3.15 inches above the normal.

The rains did not interfere with cultivation except in the case of cane, which suffered in this respect in the last decades. Harvesting of coffee, cacao, cotton, cane, cereals, and vegetables continued with rather favorable yields.

At Rio de Janeiro the weather was generally fine; there was only one period of unsettled conditions. There was little cloudiness, only six days being recorded as cloudy. Temperatures averaged above normal; the departures for mean maximum and mean minimum were 2.7° and 2.5° F., respectively. The temperature extremes recorded in the Federal District were 96° at Tijuca and 50° at Campo dos Affonsos. The total precipitation, distributed over nine days, was 1.01 inches, or 2.30 inches below the normal. The duration of sunshine exceeded the normal for May by 32.6 hours. The prevailing winds were from the north quadrant; at times they were rather strong and on the 4th a maximum velocity of 42 miles per hour was recorded.—*Translated by W. W. Reed.*

# BIBLIOGRAPHY

C. FITZHUGH TALMAN, in charge of Library

## RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

**Beman, Lamar T., comp.**
Flood control. New York. 1928. 162 p. 20 cm. (Ref. shelf. v. 5, no. 7.)

**Brockmann-Jerosch, H.**
Die Vegetation der Schweiz. 1ste. Lief. Zürich. 1925. 160 p. figs. plates (fold.) 23½ cm. (Pflanzengeog. Komm. Schweiz. Naturforsch. Gesell. Beiträge geobotan. Landesaufnahme 12.) [Contains meteorological data.]

**Carrick, D. B.**
Effect of freezing on the respiration of the apple. Ithaca. 1927. 28 p. figs. 23 cm. (Cornell univ. Agric. exper. sta. Mem. 110. March, 1928.)

**Coleman, D. A., & Boerner, E. G.**
Brown-Duvel moisture tester and how to operate it. Washington. 1927. 44 p. illus. 23½ cm. (U. S. Dept. agric. Dept. bull. no. 1375. Issued Feb. 1926. Rev. Dec. 1927.)

**Guillaume, A.**
Les sols & le climat de la Cochinchine au regard de la culture de la canne à sucre. Paris. 1927. 47 p. plates. 24 cm. (Gouv. gen. de l'Indochine. Pub. de l'agence économique.)

**Great Britain. Illumination research committee.**
Penetration of daylight and sunlight into buildings. London. 1927. v, 21 cm. figs. plates (fold.) 25 cm. (Dept. sci. and indus. res. Illum. res. Tech. paper no. 7.)

**Munson, Edward L.**
What price California climate? p. 28–33. illus. 29 cm. [Sunset, v. 60, no. 6, June, 1928.]

**Sayre, J. D.**
Recording atmometer. p. 123–125. illus. 28 cm. (Repr.: Ecology, v. 9, no. 2, Apr., 1928.)

**Vincent, J.**
Sur l'origine et la constitution des cyclones. Bruxelles. 1928. 43 p. figs. 25½ cm.

**Ward, Robert DeC.**
Proposed guide-book to the world's weather and climates. p. 67–94. 26 cm. (Repr.: Proc. Amer. phil. soc. v. 67, no. 1, 1928.)

# SOLAR OBSERVATIONS

## SOLAR AND SKY RADIATION MEASUREMENTS DURING JUNE, 1928

By HERBERT H. KIMBALL, Solar Radiation Investigations

For a description of instruments and exposures and an account of the method of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1924, **52**:42; January, 1925, **53**:29, and July, 1925, **53**:318.

Table 1 shows that solar radiation intensities were slightly above the normal values for June at all three stations. At Madison, Wis., an intensity of 1.45 gram-calories per minute per square centimeter measured at 11 a. m. of June 14, through air mass 1.09 is the highest intensity ever measured at that station in June.

Table 2 shows that the total solar radiation received on a horizontal surface directly from the sun and diffusely from the sky was below the June normal at the three stations for which normals have been determined.

Skylight polarization measurements at Washington made on six days give a mean of 50 per cent, with a maximum of 56 per cent on the 9th. At Madison measurements made on two days give a mean of 66 per cent with a maximum of 70 per cent on the 14th. These are slightly above the correspomding average values for June at both stations.

TABLE 1.—*Solar radiation intensities during June, 1928*

[Gram-calories per minute per square centimeter of normal surface]

| Date | 8 a.m. | 78.7° | 75.7° | 70.7° | 60.0° | 0.0° | 60.0° | 70.7° | 75.7° | 78.7° | Noon |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 75th mer. time | Air mass A. M. | | | | | Air mass P. M. | | | | Local mean solar time |
| | e. | 5.0 | 4.0 | 3.0 | 2.0 | [1] 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | e |
| **Washington, D. C.** | | | | | | | | | | | |
| | mm. | cal. | cal. | cal. | cal. | cal. | cal. | cal. | cal. | cal. | mm. |
| June 8 | 11.38 | | 0.68 | 0.84 | 0.89 | | | | | | 10.97 |
| 9 | 13.61 | | | | | 1.29 | | | | | 14.10 |
| 14 | 20.24 | | | | | 1.32 | | | | | 16.20 |
| 15 | 12.68 | | | | | 1.25 | | | | | 12.24 |
| 16 | 6.76 | | | | 1.06 | 1.28 | | | | | 5.79 |
| 25 | 17.37 | | | | 1.12 | 1.28 | | | | | 16.79 |
| 27 | 11.38 | | 0.69 | 0.87 | 1.08 | 1.30 | | | | | 10.59 |
| 28 | 13.61 | | 0.65 | 0.82 | 1.00 | | | | | | 11.38 |
| 30 | 15.65 | | | | 0.90 | 1.06 | | | | | 12.68 |
| Means | | | (0.67) | 0.84 | 1.01 | 1.25 | | | | | |
| Departures | | | +0.02 | +0.09 | +0.10 | +0.03 | | | | | |
| **Madison, Wis.** | | | | | | | | | | | |
| June 2 | 5.79 | | | | 1.26 | | | | | | 6.27 |
| 7 | 6.27 | | | | 1.06 | | | | | | 9.83 |
| 14 | 9.47 | | 0.87 | 1.01 | 1.17 | 1.48 | | | | | 6.76 |
| 15 | 7.29 | | | 0.94 | 1.13 | 1.36 | | | | | 7.29 |
| 26 | 7.29 | | | | | 1.35 | | | | | 9.14 |
| Means | | | (0.87) | (0.98) | 1.16 | 1.40 | | | | | |
| Departures | | | −0.01 | +0.01 | −0.05 | +0.08 | | | | | |
| **Lincoln, Nebr.** | | | | | | | | | | | |
| July 1 | 8.18 | | | | | 1.38 | 1.22 | 1.05 | 0.92 | | 5.79 |
| 13 | 8.48 | | 0.95 | 1.08 | | | | | | | 6.76 |
| 14 | 7.87 | | 0.96 | 1.04 | 1.20 | 1.44 | | | | | 9.14 |
| 21 | 12.24 | | 0.80 | 0.98 | 1.15 | 1.35 | | | | | 10.59 |
| 25 | 9.14 | | | 1.00 | 1.17 | | | | | | 6.76 |
| Means | | | 0.90 | 1.02 | 1.17 | 1.39 | (1.22) | (1.05) | (0.92) | | |
| Departures | | | +0.12 | +0.08 | +0.06 | +0.03 | +0.12 | +0.14 | +0.12 | | |

[1] Extrapolated.

TABLE 2.—*Solar and sky radiation received on a horizontal surface*

[Gram-calories per square centimeter of horizontal surface]

| Week beginning— | Average daily radiation: Washington | Madison | Lincoln | Chicago | New York | Twin Falls | Average daily departure from normal: Washington | Madison | Lincoln |
|---|---|---|---|---|---|---|---|---|---|
| 1928 | cal. | cal. | cal. | cal. | cal. | cal. | cal. | cal. | cal. |
| June 4 | 449 | 394 | 393 | 250 | 336 | | −33 | −119 | −164 |
| June 11 | 469 | 573 | 550 | 522 | 485 | 490 | −23 | +67 | +36 |
| June 18 | 345 | 364 | 440 | 290 | 218 | 684 | −124 | −155 | −111 |
| June 25 [1] | 552 | 438 | 408 | 280 | 393 | 670 | +36 | −101 | −107 |
| Excess or deficiency since first of year on July 1 | | | | | | | −1,532 | −480 | −1,346 |

[1] 8-day mean.

## POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. C. S. Freeman, Superintendent U. S. Naval Observatory]

[Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, and Mount Wilson Observatories]

[The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

| Date | Eastern standard civil time | Heliographic: Diff. long. | Longitude | Latitude | Area: Spot | Group | Total area for each day |
|---|---|---|---|---|---|---|---|
| 1928 | h. m. | ° | ° | ° | | | |
| June 1 (Naval Observatory). | 11 38 | −33.0 | 182.7 | −17.5 | | 62 | |
| | | −27.5 | 188.2 | +8.0 | | 15 | |
| | | −21.0 | 194.7 | +8.5 | 123 | | |
| | | −16.0 | 199.7 | −13.0 | | 432 | |
| | | −7.5 | 208.2 | +10.5 | | 62 | |
| | | +0.5 | 216.2 | +8.5 | | 46 | |
| | | +13.0 | 228.7 | −10.5 | | 40 | |
| | | +36.0 | 251.7 | +9.0 | 15 | | |
| | | +66.5 | 282.2 | +12.0 | 46 | | |
| | | +69.0 | 284.7 | −17.0 | 62 | | |
| | | +78.0 | 293.7 | −19.0 | 77 | | 980 |
| June 2 (Naval Observatory). | 11 17 | −68.0 | 134.7 | +15.0 | | 25 | |
| | | −39.5 | 163.2 | −9.0 | | 9 | |
| | | −36.0 | 166.7 | +7.5 | 9 | | |
| | | −34.0 | 168.7 | +11.0 | | 31 | |
| | | −20.5 | 182.2 | −17.0 | | 37 | |
| | | −8.5 | 194.2 | +8.0 | 123 | | |
| | | −3.5 | 199.2 | −13.0 | | 340 | |
| | | +6.0 | 208.7 | +10.5 | | 31 | |
| | | +13.0 | 215.7 | +9.0 | | 15 | |
| | | +28.0 | 230.7 | −10.5 | | 6 | |
| | | +49.5 | 252.2 | +9.0 | | 6 | |
| | | +80.0 | 282.7 | +11.0 | 31 | | 663 |
| June 3 (Naval Observatory). | 12 28 | −19.0 | 169.8 | +11.0 | | 62 | |
| | | −7.5 | 181.3 | −17.0 | 31 | | |
| | | +6.0 | 194.8 | +8.0 | | 216 | |
| | | +10.0 | 198.8 | −13.5 | | 278 | |
| | | +20.0 | 208.8 | +10.5 | | 15 | |
| | | +28.5 | 217.3 | +9.5 | | 37 | |
| | | +29.0 | 217.8 | −10.0 | | 15 | |
| | | +62.0 | 250.8 | +9.0 | 31 | | 685 |
| June 4 (Mount Wilson) | 11 30 | −29.5 | 146.6 | +21.0 | | 2 | |
| | | −6.0 | 170.1 | +11.0 | | 45 | |
| | | +6.0 | 182.1 | −16.0 | | 27 | |
| | | +19.0 | 195.1 | +8.5 | | 347 | |
| | | +23.0 | 199.1 | −13.0 | | 413 | |
| | | +32.0 | 208.1 | −20.0 | | 14 | |
| | | +37.0 | 213.1 | +8.0 | | 33 | |
| | | +42.0 | 218.1 | −10.0 | | 15 | 896 |
| June 5 (Naval Observatory). | 11 36 | −15.0 | 147.8 | +19.5 | | 62 | |
| | | +2.5 | 165.3 | +9.0 | | 62 | |
| | | +7.0 | 169.8 | +8.5 | | 46 | |
| | | +11.0 | 173.8 | +11.0 | 6 | | |
| | | +18.5 | 181.3 | −18.5 | | 31 | |
| | | +31.5 | 194.3 | +8.0 | | 154 | |
| | | +35.0 | 197.8 | −13.0 | | 216 | |
| | | +52.0 | 214.8 | +9.0 | | 9 | |
| | | +54.0 | 216.8 | −10.0 | | 46 | 632 |
| June 6 (Naval Observatory). | 12 1 | −79.0 | 70.3 | −7.0 | 15 | | |
| | | −2.5 | 146.8 | +20.0 | | 31 | |
| | | +1.5 | 150.8 | +19.0 | 37 | | |
| | | +15.5 | 164.8 | +8.0 | | 185 | |
| | | +20.5 | 169.8 | +8.0 | | 139 | |
| | | +31.0 | 180.3 | −18.0 | 15 | | |
| | | +47.0 | 196.3 | +7.5 | | 93 | |
| | | +48.0 | 197.3 | −14.5 | | 37 | |
| | | +49.5 | 198.8 | −11.5 | 77 | | |
| | | +68.0 | 217.3 | −10.0 | | 46 | 675 |
| June 7 (Naval Observatory). | 11 43 | −72.0 | 64.3 | −11.0 | 154 | | |
| | | −65.0 | 71.3 | −12.0 | 15 | | |
| | | −42.5 | 93.8 | −11.0 | | 12 | |
| | | +11.0 | 147.3 | +20.0 | | 31 | |
| | | +16.0 | 152.3 | +18.5 | 77 | | |
| | | +28.0 | 164.3 | +7.5 | 139 | | |
| | | +32.0 | 168.3 | +10.5 | | 123 | |
| | | +35.0 | 171.3 | +8.0 | 139 | | |
| | | +44.5 | 180.8 | −17.5 | 9 | | |
| | | +59.0 | 195.3 | +7.0 | | 154 | |
| | | +60.5 | 196.8 | −15.0 | | 31 | |
| | | +63.5 | 199.8 | −11.5 | 77 | | |
| | | +77.5 | 213.8 | −20.0 | 31 | | 992 |

## POSITIONS AND AREAS OF SUN SPOTS—Continued

[Communicated by Capt. C. S. Freeman, Superintendent U. S. Naval Observatory]

[Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, and Mount Wilson Observatories]

[The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

| Date | Eastern standard civil time | | Heliographic | | | Area | | Total area for each day |
|---|---|---|---|---|---|---|---|---|
| | | | Diff. long. | Longi-tude | Lati-tude | Spot | Group | |
| 1928 | h. | m. | ° | ° | ° | | | |
| June 8 (Naval Observatory.) | 11 | 50 | −59.0 | 64.0 | −11.0 | -------- | 93 | -------- |
| | | | −52.0 | 71.0 | −12.0 | 15 | -------- | -------- |
| | | | +21.5 | 144.5 | +20.5 | -------- | 31 | -------- |
| | | | +30.0 | 153.0 | +18.5 | 77 | -------- | -------- |
| | | | +41.5 | 164.5 | +8.0 | -------- | 170 | -------- |
| | | | +48.0 | 171.0 | +8.0 | 185 | -------- | -------- |
| | | | +50.5 | 173.5 | +10.5 | 62 | -------- | -------- |
| | | | +72.5 | 195.5 | +6.5 | 108 | -------- | -------- |
| | | | +77.5 | 200.5 | −11.0 | 93 | -------- | 834 |
| June 9 (Naval Observatory). | 11 | 9 | −46.0 | 64.1 | −10.5 | -------- | 77 | -------- |
| | | | +37.5 | 147.6 | +20.0 | 15 | -------- | -------- |
| | | | +44.5 | 154.6 | +18.5 | 62 | -------- | -------- |
| | | | +54.5 | 164.6 | +7.5 | -------- | 185 | -------- |
| | | | +61.5 | 171.6 | +8.0 | 247 | -------- | -------- |
| | | | +65.0 | 175.1 | +10.5 | -------- | 77 | 663 |
| June 10 (Naval Observatory.) | 11 | 26 | −31.0 | 65.7 | −10.5 | -------- | 46 | -------- |
| | | | −22.5 | 74.2 | −10.5 | -------- | 9 | -------- |
| | | | +60.0 | 156.7 | +19.0 | 77 | -------- | -------- |
| | | | +68.5 | 165.2 | +8.0 | 170 | -------- | -------- |
| | | | +73.5 | 170.2 | +8.0 | 247 | -------- | -------- |
| | | | +75.0 | 171.7 | +10.5 | -------- | 154 | 703 |
| June 11 (Harvard)-------- | 11 | 11 | +72.0 | 155.0 | +18.5 | 54 | -------- | 54 |
| June 12 (Harvard)-------- | 11 | 53 | −5.5 | 65.0 | −10.0 | -------- | 31 | 31 |
| June 13 (Naval Observatory). | 12 | 38 | −50.0 | 6.3 | +12.0 | -------- | 46 | -------- |
| | | | −46.5 | 9.8 | +12.0 | -------- | 31 | -------- |
| | | | −45.0 | 11.3 | −10.5 | -------- | 9 | -------- |
| | | | +7.0 | 63.3 | −10.5 | -------- | 25 | 111 |
| June 14 (Naval Observatory. | 11 | 43 | −37.5 | 6.1 | +12.0 | -------- | 170 | -------- |
| | | | −36.0 | 7.6 | +12.5 | -------- | 46 | -------- |
| | | | +19.5 | 63.1 | −10.0 | 3 | -------- | 219 |
| June 15 (Naval Observatory). | 11 | 43 | −59.5 | 330.9 | +16.0 | 6 | -------- | -------- |
| | | | −23.0 | 7.4 | +12.0 | -------- | 201 | -------- |
| | | | −20.5 | 9.9 | −15.5 | -------- | 46 | -------- |
| | | | −17.5 | 12.9 | +12.5 | 123 | -------- | -------- |
| | | | −12.0 | 18.4 | −12.5 | -------- | 6 | 382 |
| June 16 (Naval Observatory). | 11 | 16 | −85.0 | 292.4 | +9.0 | 154 | -------- | -------- |
| | | | −9.5 | 7.9 | +11.5 | -------- | 154 | -------- |
| | | | −9.5 | 7.9 | −16.0 | -------- | 93 | -------- |
| | | | −6.5 | 10.9 | −15.0 | 139 | -------- | -------- |
| | | | −4.5 | 12.9 | +12.0 | 139 | -------- | -------- |
| | | | +0.5 | 17.9 | −12.5 | -------- | 6 | 685 |
| June 17 (Naval Observatory). | 11 | 33 | −71.5 | 292.5 | +9.0 | 185 | -------- | -------- |
| | | | −67.0 | 297.0 | +13.0 | -------- | 123 | -------- |
| | | | +2.5 | 6.5 | −16.5 | -------- | 93 | -------- |
| | | | +3.5 | 7.5 | +11.5 | -------- | 62 | -------- |
| | | | +7.5 | 11.5 | −15.5 | 139 | -------- | -------- |
| | | | +8.5 | 12.5 | +12.0 | 185 | -------- | 787 |
| June 18 (Naval Observa- | 11 | 37 | −65.0 | 285.7 | +13.5 | 6 | -------- | -------- |
| | | | −58.5 | 292.2 | +9.0 | -------- | 170 | -------- |
| | | | −53.5 | 297.2 | +13.0 | -------- | 62 | -------- |
| | | | +12.0 | 2.7 | +7.0 | -------- | 6 | -------- |
| | | | +16.0 | 6.7 | +18.0 | -------- | 37 | -------- |
| | | | +17.0 | 7.7 | +11.0 | -------- | 46 | -------- |
| | | | +18.5 | 9.2 | −17.0 | -------- | 170 | -------- |
| | | | +22.0 | 12.7 | +11.5 | 185 | -------- | 682 |
| June 19 (Naval Observatory). | 13 | 42 | −50.5 | 285.8 | +13.0 | 9 | -------- | -------- |
| | | | −43.5 | 292.8 | +9.0 | 139 | -------- | -------- |
| | | | −38.5 | 297.8 | +13.0 | -------- | 62 | -------- |
| | | | +27.0 | 3.3 | +8.0 | -------- | 62 | -------- |
| | | | +30.5 | 6.8 | +19.0 | -------- | 62 | -------- |
| | | | +32.0 | 8.3 | −15.5 | -------- | 154 | -------- |
| | | | +35.0 | 11.3 | +12.5 | -------- | 370 | 858 |
| June 20 (Naval Observatory). | 14 | 1 | −30.5 | 292.4 | +9.0 | 139 | -------- | -------- |
| | | | −24.0 | 298.9 | +13.5 | -------- | 15 | -------- |
| | | | +40.0 | 2.9 | +8.0 | -------- | 62 | -------- |
| | | | +43.5 | 6.4 | +19.0 | -------- | 46 | -------- |
| | | | +46.5 | 9.4 | −16.0 | -------- | 154 | -------- |
| | | | +48.0 | 10.9 | +12.5 | -------- | 463 | 879 |
| June 21 (Mount Wilson)-- | 9 | 45 | −80.0 | 232.0 | −12.0 | 119 | -------- | -------- |
| | | | −41.0 | 271.0 | +16.0 | -------- | 20 | -------- |
| | | | −18.0 | 294.0 | +10.0 | -------- | 213 | -------- |
| | | | −17.0 | 295.0 | +15.0 | -------- | 23 | -------- |
| | | | +53.0 | 5.0 | +8.0 | -------- | 17 | -------- |
| | | | +55.0 | 7.0 | +18.0 | -------- | 13 | -------- |
| | | | +58.5 | 10.5 | −16.5 | -------- | 58 | -------- |
| | | | +59.0 | 11.0 | +12.0 | -------- | 764 | -------- |
| | | | +73.0 | 25.0 | −9.0 | -------- | 24 | 1,251 |

## POSITIONS AND AREAS OF SUN SPOTS—Continued

[Communicated by Capt. C. S. Freeman, Superintendent U. S. Naval Observatory]

[Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, and Mount Wilson Observatories]

[The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

| Date | Eastern standard civil time | | Heliographic | | | Area | | Total area for each day |
|---|---|---|---|---|---|---|---|---|
| | | | Diff. long. | Longi-tude | Lati-tude | Spot | Group | |
| 1928 | h. | m. | ° | ° | ° | | | |
| June 22 (Mount Wilson)-- | 10 | 0 | −86.0 | 212.6 | −20.0 | 167 | -------- | -------- |
| | | | −76.0 | 222.6 | +10.5 | -------- | 7 | -------- |
| | | | −66.0 | 232.6 | −12.0 | 235 | -------- | -------- |
| | | | −54.0 | 244.6 | +9.0 | -------- | 5 | -------- |
| | | | −27.5 | 271.1 | +13.0 | -------- | 6 | -------- |
| | | | −14.0 | 284.6 | +10.0 | -------- | 15 | -------- |
| | | | −6.5 | 292.1 | +10.0 | -------- | 253 | -------- |
| | | | −3.0 | 295.6 | +12.5 | -------- | 19 | -------- |
| | | | +67.0 | 5.6 | +17.0 | 29 | -------- | -------- |
| | | | +70.5 | 9.1 | −16.0 | -------- | 12 | -------- |
| | | | +73.0 | 11.6 | +12.0 | 934 | -------- | 1,682 |
| June 23 (Mount Wilson)-- | 9 | 45 | −82.0 | 203.5 | +15.0 | -------- | 152 | -------- |
| | | | −73.0 | 212.5 | −21.0 | -------- | 513 | -------- |
| | | | −63.0 | 222.5 | +9.0 | -------- | 64 | -------- |
| | | | −53.0 | 232.5 | −12.5 | 212 | -------- | -------- |
| | | | −40.0 | 245.5 | +7.0 | -------- | 34 | -------- |
| | | | −15.0 | 270.5 | +14.0 | -------- | 8 | -------- |
| | | | −4.0 | 281.5 | +9.0 | -------- | 8 | -------- |
| | | | +7.5 | 293.0 | +11.0 | -------- | 339 | -------- |
| | | | +16.0 | 301.5 | +12.0 | -------- | 9 | -------- |
| | | | +80.0 | 5.5 | +18.0 | 16 | -------- | -------- |
| | | | +85.0 | 10.5 | +13.0 | 168 | -------- | 1,523 |
| June 24 (Naval Observatory). | 11 | 18 | −72.0 | 199.5 | +17.5 | -------- | 556 | -------- |
| | | | −63.0 | 208.5 | +14.5 | -------- | 62 | -------- |
| | | | −62.5 | 209.0 | −21.5 | -------- | 154 | -------- |
| | | | −55.0 | 216.5 | −20.0 | 278 | -------- | -------- |
| | | | −51.0 | 220.5 | +9.5 | -------- | 77 | -------- |
| | | | −47.0 | 224.5 | +11.5 | 108 | -------- | -------- |
| | | | −38.0 | 233.5 | −12.0 | -------- | 185 | -------- |
| | | | −25.0 | 246.5 | +8.0 | -------- | 93 | -------- |
| | | | −14.0 | 257.5 | +3.5 | -------- | 31 | -------- |
| | | | +1.5 | 273.0 | +13.5 | -------- | 62 | -------- |
| | | | +21.5 | 293.0 | +9.5 | -------- | 247 | 1,853 |
| June 25 (Naval Observatory). | 12 | 15 | −58.0 | 199.7 | +17.5 | -------- | 586 | -------- |
| | | | −50.5 | 207.2 | −21.5 | -------- | 108 | -------- |
| | | | −49.0 | 208.7 | +14.0 | -------- | 93 | -------- |
| | | | −41.5 | 216.2 | −20.5 | -------- | 309 | -------- |
| | | | −39.0 | 218.7 | +9.5 | 40 | -------- | -------- |
| | | | −33.0 | 224.7 | +11.5 | 108 | -------- | -------- |
| | | | −25.0 | 232.7 | −12.0 | -------- | 170 | -------- |
| | | | −10.5 | 247.2 | +8.0 | -------- | 139 | -------- |
| | | | −2.0 | 255.7 | +3.5 | -------- | 31 | -------- |
| | | | +14.5 | 272.2 | +13.5 | -------- | 77 | -------- |
| | | | +35.0 | 292.7 | +9.5 | -------- | 216 | 1,877 |
| June 26 (Naval Observatory). | 11 | 42 | −72.5 | 172.3 | +8.0 | 62 | -------- | -------- |
| | | | −46.0 | 198.8 | +17.5 | -------- | 648 | -------- |
| | | | −38.5 | 206.3 | −22.0 | -------- | 46 | -------- |
| | | | −37.0 | 207.8 | +14.0 | -------- | 46 | -------- |
| | | | −28.0 | 216.8 | −20.5 | -------- | 370 | -------- |
| | | | −25.5 | 219.3 | +9.5 | -------- | 15 | -------- |
| | | | −20.0 | 224.8 | +11.5 | 62 | -------- | -------- |
| | | | −12.0 | 232.8 | −12.0 | -------- | 133 | -------- |
| | | | −6.5 | 238.3 | −11.0 | -------- | 25 | -------- |
| | | | +.5 | 245.3 | +8.0 | -------- | 31 | -------- |
| | | | +5.5 | 250.3 | +8.0 | 62 | -------- | -------- |
| | | | +11.0 | 255.8 | +3.5 | 9 | -------- | -------- |
| | | | +26.0 | 270.8 | +12.0 | -------- | 31 | -------- |
| | | | +48.0 | 292.8 | +9.5 | -------- | 216 | 1,756 |
| June 27 (Naval Observatory). | 11 | 46 | −72.5 | 150.0 | +19.0 | -------- | 123 | -------- |
| | | | −60.0 | 171.5 | +9.0 | 46 | -------- | -------- |
| | | | −36.5 | 195.0 | +18.0 | -------- | 247 | -------- |
| | | | −29.5 | 202.0 | +18.0 | -------- | 247 | -------- |
| | | | −25.5 | 206.0 | −21.5 | -------- | 31 | -------- |
| | | | −22.0 | 209.5 | +16.5 | -------- | 37 | -------- |
| | | | −15.5 | 216.0 | −19.5 | -------- | 494 | -------- |
| | | | −11.5 | 220.0 | +10.5 | -------- | 6 | -------- |
| | | | −7.5 | 224.0 | +12.0 | 83 | -------- | -------- |
| | | | +1.0 | 232.5 | −11.5 | 108 | -------- | -------- |
| | | | +8.0 | 239.5 | −9.5 | -------- | 31 | -------- |
| | | | +17.0 | 248.5 | +8.5 | -------- | 154 | -------- |
| | | | +47.0 | 278.5 | +6.0 | 12 | -------- | -------- |
| | | | +61.5 | 293.0 | +11.0 | -------- | 340 | 1,959 |
| June 28 (Naval Observatory). | 11 | 47 | −64.5 | 153.7 | +4.5 | -------- | 15 | -------- |
| | | | −59.5 | 158.7 | +19.0 | -------- | 108 | -------- |
| | | | −46.5 | 171.7 | +8.0 | 46 | -------- | -------- |
| | | | −22.5 | 195.7 | +18.0 | 278 | -------- | -------- |
| | | | −17.0 | 201.2 | +18.0 | -------- | 216 | -------- |
| | | | −10.0 | 208.2 | −23.5 | 9 | -------- | -------- |
| | | | −9.0 | 209.2 | +15.5 | -------- | 31 | -------- |
| | | | −2.5 | 215.7 | −19.5 | -------- | 463 | -------- |
| | | | +3.0 | 221.2 | +10.5 | -------- | 15 | -------- |
| | | | +7.5 | 225.7 | +11.5 | 62 | -------- | -------- |
| | | | +14.5 | 232.7 | −11.5 | 123 | -------- | -------- |
| | | | +21.5 | 239.7 | −10.0 | -------- | 22 | -------- |
| | | | +30.0 | 248.2 | +8.5 | -------- | 154 | -------- |
| | | | +73.5 | 291.7 | +11.0 | -------- | 309 | 1,851 |

### POSITIONS AND AREAS OF SUN SPOTS—Continued

[Communicated by Capt. C. S. Freeman, Superintendent U. S. Naval Observatory]

[Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, and Mount Wilson Observatories]

[The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

| Date | Eastern standard civil time | Heliographic | | | Area | | Total area for each day |
|---|---|---|---|---|---|---|---|
| | | Diff. long. | Longitude | Latitude | Spot | Group | |
| 1928 | h. m. | ° | ° | ° | | | |
| June 29 (Naval Observatory). | 11 51 | −50.5 | 154.5 | +5.0 | ------- | 25 | ------- |
| | | −46.5 | 158.5 | +19.0 | ------- | 46 | ------- |
| | | −45.0 | 160.0 | +5.0 | 6 | ------- | ------- |
| | | −32.5 | 172.5 | +8.0 | 43 | ------- | ------- |
| | | −14.0 | 191.0 | +10.0 | 3 | ------- | ------- |
| | | −9.5 | 195.5 | +18.0 | 216 | ------- | ------- |
| | | −4.0 | 201.0 | +18.0 | ------- | 108 | ------- |
| | | +3.0 | 208.0 | +17.0 | ------- | 46 | ------- |
| | | +10.5 | 215.5 | −19.5 | ------- | 463 | ------- |
| | | +20.0 | 225.0 | +11.5 | 52 | ------- | ------- |
| | | +28.5 | 233.5 | −12.0 | 108 | ------- | ------- |
| | | +34.0 | 239.0 | −10.0 | ------- | 3 | ------- |
| | | +44.5 | 249.5 | +9.0 | ------- | 93 | 1,212 |
| June 30 (Harvard)------- | 8 50 | −36.5 | 157.0 | +6.5 | ------- | 56 | ------- |
| | | −35.0 | 158.5 | +20.0 | ------- | 39 | ------- |
| | | −22.0 | 171.5 | +9.0 | 65 | ------- | ------- |
| | | +6.0 | 199.5 | +18.0 | ------- | 573 | ------- |
| | | +23.5 | 217.0 | −20.0 | ------- | 880 | ------- |
| | | +30.5 | 224.0 | +12.5 | ------- | 54 | ------- |
| | | +39.0 | 232.5 | −12.5 | 203 | ------- | ------- |
| | | +56.5 | 250.0 | +9.0 | 113 | ------- | 1,983 |
| Mean daily area for June. | ------- | ------- | ------- | ------- | ------- | ------- | 979 |

### PROVISIONAL SUNSPOT RELATIVE NUMBERS FOR MAY, 1928

[Data furnished by Prof. A. Wolfer, University of Zurich, Switzerland]

| May | Relative numbers | May | Relative numbers | May | Relative numbers |
|---|---|---|---|---|---|
| 1------- | 124 | 11------- | 85 | 21------- | 14 |
| 2------- | 126 | 12------- | 62 | 22------- | 22 |
| 3------- | 126 | 13------- | 34 | 23------- | 41 |
| 4------- | 109 | 14------- | 26 | 24------- | 34 |
| 5------- | 114 | 15------- | 15 | 25------- | 49 |
| 6------- | 117 | 16------- | 16 | 26------- | 40 |
| 7------- | 142 | 17------- | 15 | 27------- | 54 |
| 8------- | 133 | 18------- | 13 | 28------- | 112 |
| 9------- | 146 | 19------- | 15 | 29------- | 139 |
| 10------- | 119 | 20------- | 0? | 30------- | 150 |
| | | | | 31------- | 153 |

Number of observations, 31; mean, 75.6.

### PROVISIONAL SUNSPOT RELATIVE NUMBERS FOR JUNE, 1928

[Data furnished by Prof. A. Wolfer, University of Zurich, Switzerland]

| June | Relative numbers | June | Relative numbers | June | Relative numbers |
|---|---|---|---|---|---|
| 1------- | 134 | 11------- | 24 | 21------- | 89 |
| 2------- | 133 | 12------- | 7 | 22------- | 109 |
| 3------- | 110 | 13------- | 29 | 23------- | 131 |
| 4------- | 100 | 14------- | 25 | 24------- | 145 |
| 5------- | 98 | 15------- | 43 | 25------- | 154 |
| 6------- | 90 | 16------- | 53 | 26------- | 134 |
| 7------- | 95 | 17------- | 64 | 27------- | 145 |
| 8------- | 74 | 18------- | 62 | 28------- | 126 |
| 9------- | 43 | 19------- | 94 | 29------- | 134 |
| 10------- | 32 | 20------- | 63 | 30------- | 114 |

Number of observations, 30; mean, 88.5.

# AEROLOGICAL OBSERVATIONS

By W. R. STEVENS

Free-air temperatures for June were mostly below normal except at Washington. Aside from a gradual increase at Ellendale, departures from normal decreased with altitude. It was the coolest June of record at Broken Arrow and Royal Center, and with but one exception at Due West and Ellendale. The lowest June temperature was recorded during the month at the two latter stations.

Relative humidities averaged slightly above normal.

Vapor pressures were somewhat above normal at Broken Arrow, Due West and Washington, and below at Ellendale, Groesbeck and Royal Center.

Resultant winds were almost entirely of southerly component at and near the surface. The area of winds of northerly component gradually increased with altitude from north to south, and at an altitude of 6,000 meters included practically the entire country.

Every station obtained an unusually large numoer of kite flights shortly before the occurrence of thunderstorms and a few when the storms were in progress. In one instance it is believed that the wire was actually struck by lightning. The official in charge at Ellendale says in this connection:

At about 2,600 meters out, while reeling in the flight of the 27th, the head kite broke away with about 200 meters of wire. The cause of the break is not definitely known but from the appearance of the kite bridle, which was slightly burned, it would seem that a mild lightning discharge struck it. This flight is of more or less interest in that it was made in a somewhat threatening condition. Light rain fell during the flight, beginning at 8.22 a. m. and continuing through the flight. The conditions were ripe for thunderstorm development. Static discharges were high, some measurements being greatly in excess of 10,000 volts.—*L. A. Warren.*

Special observations were made on the 28th, 29th and 30th at a number of selected balloon stations and forwarded to Detroit for the information of contestants in the international Gordon Bennett balloon race.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during June, 1928*

TEMPERATURE (° C.)

| Altitude m. s. l. (meters) | Broken Arrow, Okla. (233 meters) | | Due West, S. C. (217 meters) | | Ellendale, N. Dak. (444 meters) | | Groesbeck, Tex. (141 meters) | | Royal Center, Ind. (225 meters) | | Washington, D. C.[1] (7 meters) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Departure from normal | Mean | Departure from normal | Mean | Departure from normal | Mean | Departure from normal | Mean | Departure from normal | Mean | Departure from normal |
| Surface------ | 23.4 | −1.5 | 24.6 | −1.4 | 16.2 | −2.5 | 23.9 | −2.0 | 17.5 | −4.3 | 26.2 | +2.3 |
| 250------ | 23.2 | −1.6 | 24.2 | −1.4 | ------ | ------ | 23.0 | −1.9 | 17.2 | −4.3 | 22.5 | +2.1 |
| 500------ | 21.1 | −1.8 | 21.7 | −1.3 | 15.8 | −2.5 | 21.0 | −1.9 | 15.7 | −3.2 | 21.0 | +1.2 |
| 750------ | 19.6 | −1.8 | 20.2 | −1.1 | 14.0 | −2.7 | 19.9 | −1.5 | 14.3 | −2.8 | 19.3 | +0.9 |
| 1,000------ | 18.3 | −1.8 | 18.6 | −1.1 | 12.5 | −2.8 | 19.7 | −0.6 | 12.9 | −2.7 | 17.3 | +0.6 |
| 1,250------ | 17.0 | −1.8 | 17.2 | −0.9 | 10.6 | −3.4 | 19.3 | +0.1 | 11.8 | −2.3 | 15.5 | +0.4 |
| 1,500------ | 15.9 | −1.6 | 15.7 | −0.7 | 9.2 | −3.5 | 18.9 | +0.8 | 10.7 | −2.1 | 13.7 | +0.1 |
| 2,000------ | 14.1 | −0.7 | 12.6 | −0.5 | 6.2 | −3.6 | 16.8 | +1.0 | 8.5 | −1.7 | 10.4 | −0.2 |
| 2,500------ | 12.2 | +0.2 | 9.6 | −0.4 | 2.9 | −4.0 | 14.0 | +0.8 | 6.5 | −1.0 | 7.5 | −0.4 |
| 3,000------ | 9.6 | +0.6 | 6.4 | −0.5 | −0.1 | −4.2 | 10.8 | +0.3 | 4.3 | −0.5 | 4.6 | −0.4 |
| 3,500------ | 7.4 | +1.5 | 3.6 | −0.1 | −3.3 | −4.5 | ------ | ------ | 2.1 | −0.1 | ------ | ------ |
| 4,000------ | 5.6 | +2.8 | 0.4 | −0.4 | −6.1 | −4.5 | ------ | ------ | 0.1 | +0.3 | ------ | ------ |
| 4,500------ | ------ | ------ | −2.4 | −0.8 | −9.3 | −4.6 | ------ | ------ | −1.7 | +1.2 | ------ | ------ |
| 5,000------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ |

[1] Naval air station.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during June, 1928*—Continued

RELATIVE HUMIDITY (%)

| Altitude m. s. l. (meters) | Broken Arrow, Okla. (233 meters) | | Due West, S. C. (217 meters) | | Ellendale, N. Dak. (444 meters) | | Groesbeck, Tex. (141 meters) | | Royal Center, Ind. (225 meters) | | Washington, D. C.[1] (7 meters) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Departure from normal | Mean | Departure from normal | Mean | Departure from normal | Mean | Departure from normal | Mean | Departure from normal | Mean | Departure from normal |
| Surface | 77 | +5 | 69 | +5 | 60 | −1 | 83 | +8 | 74 | +8 | 62 | −3 |
| 250 | 77 | +5 | 70 | +6 | | | 85 | +9 | 74 | +8 | 65 | −4 |
| 500 | 80 | +8 | 73 | +6 | 68 | −1 | 87 | +9 | 72 | +5 | 68 | +2 |
| 750 | 81 | +9 | 73 | +5 | 68 | +1 | 82 | +5 | 72 | +4 | 68 | +3 |
| 1,000 | 82 | +11 | 73 | +4 | 68 | +2 | 69 | −3 | 74 | +6 | 66 | +3 |
| 1,250 | 79 | +10 | 70 | +1 | 70 | +5 | 59 | −8 | 74 | +6 | 66 | +2 |
| 1,500 | 74 | +7 | 69 | −1 | 69 | +6 | 47 | −15 | 73 | +7 | 68 | +5 |
| 2,000 | 64 | +3 | 65 | −5 | 63 | +2 | 39 | −15 | 65 | +4 | 70 | +5 |
| 2,500 | 49 | −5 | 68 | −2 | 64 | +4 | 31 | −18 | 64 | +9 | 68 | +8 |
| 3,000 | 42 | −8 | 64 | −3 | 62 | +6 | 27 | −19 | 59 | +8 | 63 | +5 |
| 3,500 | 36 | −13 | 64 | −1 | 60 | +8 | | | 60 | +15 | | |
| 4,000 | 29 | −19 | 62 | +2 | 55 | +7 | | | 72 | +32 | | |
| 4,500 | | | 62 | +10 | 64 | +17 | | | 72 | +32 | | |
| 5,000 | | | | | | | | | | | | |

[1] Naval air station.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during June, 1928*—Continued

VAPOR PRESSURE (*mb.*)

| Altitude m. s. l. (meters) | Broken Arrow, Okla. (233 meters) | | Due West, S. C. (217 meters) | | Ellendale, N. Dak. (444 meters) | | Groesbeck, Tex. (141 meters) | | Royal Center, Ind. (225 meters) | | Washington, D. C.[1] (7 meters) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Departure from normal | Mean | Departure from normal | Mean | Departure from normal | Mean | Departure from normal | Mean | Departure from normal | Mean | Departure from normal |
| Surface | 22.65 | +0.03 | 21.28 | +0.35 | 12.89 | −2.40 | 24.82 | +0.21 | 15.04 | −2.28 | 21.40 | +2.08 |
| 250 | 22.51 | +0.09 | 20.93 | +0.33 | | | 23.95 | +0.20 | 14.71 | −2.33 | 19.10 | +1.54 |
| 500 | 20.70 | +0.61 | 18.82 | +0.37 | 12.46 | −2.36 | 21.72 | +0.01 | 13.16 | −1.72 | 17.09 | +1.60 |
| 750 | 19.16 | +0.99 | 17.10 | +0.27 | 11.16 | −1.86 | 19.06 | −0.56 | 12.06 | −1.51 | 15.18 | +1.28 |
| 1,000 | 17.87 | +1.32 | 15.51 | 0.00 | 10.08 | −1.65 | 15.66 | −1.39 | 11.30 | −1.19 | 13.29 | +0.74 |
| 1,250 | 16.07 | +1.25 | 13.52 | −0.65 | 9.18 | −1.42 | 12.93 | −1.92 | 10.44 | −1.02 | 11.87 | +0.66 |
| 1,500 | 13.83 | +0.70 | 12.00 | −0.92 | 8.24 | −1.19 | 9.92 | −2.86 | 9.61 | −0.66 | 10.87 | +0.72 |
| 2,000 | 10.40 | +0.38 | 9.20 | −1.24 | 6.13 | −1.47 | 6.93 | −2.70 | 7.43 | −0.47 | 8.72 | +0.23 |
| 2,500 | 7.52 | +0.14 | 8.12 | −0.28 | 4.96 | −1.30 | 4.56 | −2.95 | 6.27 | +0.51 | 6.84 | +0.51 |
| 3,000 | 5.94 | +0.35 | 6.41 | −0.16 | 3.83 | −1.00 | 2.94 | −3.00 | 4.87 | +0.58 | 5.03 | +0.08 |
| 3,500 | 5.13 | +0.63 | 5.19 | +0.13 | 2.91 | −0.93 | | | 4.27 | +1.26 | | |
| 4,000 | 4.40 | +0.81 | 4.36 | +0.60 | 2.09 | −1.03 | | | 4.65 | +2.47 | | |
| 4,500 | | | 3.72 | +1.02 | 1.80 | −0.58 | | | 4.56 | +2.74 | | |
| 5,000 | | | | | | | | | | | | |

TABLE 2.—*Free-air resultant winds (m. p. s.) during June, 1928*

| Altitude M. S. L. (meters) | Broken Arrow, Okla. (233 meters) | | | | Due West, S. C. (217 meters) | | | | Ellendale, N. Dak. (444 meters) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | | Normal | | Mean | | Normal | | Mean | | Normal | |
| | Dir. | Vel. | Dir. | Vel. | Dir. | Vel. | Dir. | Vel. | Dir. | Vel. | Dir. | Vel. |
| Surface | S. 5° W | 3.7 | S. 6° W | 4.0 | S. 76° W | 3.8 | S. 74° W | 1.5 | N. 3° W | 0.5 | N. 56° W | 0.4 |
| 250 | S. 5° W | 3.8 | S. 6° W | 4.1 | S. 77° W | 4.4 | S. 76° W | 1.7 | | | | |
| 500 | S. 4° W | 4.4 | S. 10° W | 5.5 | S. 69° W | 6.4 | S. 76° W | 2.5 | N. 57° E | 0.3 | N. 71° W | 0.3 |
| 750 | S. 5° W | 4.6 | S. 15° W | 6.0 | S. 74° W | 7.3 | S. 77° W | 3.1 | S. 4° W | 0.9 | S. 39° W | 0.8 |
| 1,000 | S. 18° W | 4.8 | S. 24° W | 6.1 | S. 74° W | 8.4 | S. 75° W | 3.5 | S. 27° W | 1.3 | S. 48° W | 1.2 |
| 1,250 | S. 28° W | 5.3 | S. 28° W | 6.2 | S. 77° W | 9.2 | S. 79° W | 4.5 | S. 43° W | 1.3 | S. 65° W | 1.9 |
| 1,500 | S. 40° W | 5.1 | S. 33° W | 6.2 | S. 73° W | 10.0 | S. 77° W | 5.6 | S. 50° W | 1.5 | S. 69° W | 2.3 |
| 2,000 | S. 56° W | 5.8 | S. 39° W | 6.3 | S. 73° W | 11.3 | S. 81° W | 7.5 | S. 69° W | 1.9 | S. 78° W | 3.4 |
| 2,500 | S. 78° W | 6.0 | S. 43° W | 6.3 | S. 75° W | 11.3 | S. 80° W | 8.0 | N. 78° W | 2.4 | S. 83° W | 5.1 |
| 3,000 | N. 82° W | 8.6 | S. 48° W | 6.5 | S. 82° W | 11.2 | S. 85° W | 9.2 | N. 75° W | 5.2 | S. 89° W | 7.2 |
| 3,500 | N. 62° W | 11.7 | S. 54° W | 6.8 | S. 71° W | 11.6 | S. 83° W | 10.3 | S. 78° W | 7.8 | S. 89° W | 9.2 |
| 4,000 | N. 45° W | 13.4 | S. 68° W | 7.6 | W | 9.0 | S. 82° W | 9.9 | S. 84° W | 10.7 | N. 88° W | 11.7 |
| 4,500 | | | | | W | 10.0 | N. 72° W | 12.5 | N. 67° W | 19.2 | N. 79° W | 13.6 |
| 5,000 | | | | | | | | | W | 23.0 | N. 74° W | 15.3 |

| Altitude M. S. L. (meters) | Groesbeck, Tex. (141 meters) | | | | Royal Center, Ind. (225 meters) | | | | Washington, D. C. (34 meters) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | | Normal | | Mean | | Normal | | Mean | | Normal | |
| | Dir. | Vel. | Dir. | Vel. | Dir. | Vel. | Dir. | Vel. | Dir. | Vel. | Dir. | Vel. |
| Surface | S. 15° W | 5.3 | S. | 3.6 | S. 16° W | 1.7 | S. 50° W | 1.6 | S. 67° W | 0.4 | N. 47° W | 0.6 |
| 250 | S. 14° W | 7.3 | S. 1° W | 4.3 | S. 23° W | 1.8 | S. 47° W | 1.6 | N. 72° W | 1.9 | N. 60° W | 2.0 |
| 500 | S. 17° W | 11.1 | S. 6° W | 5.9 | S. 28° W | 3.9 | S. 50° W | 3.0 | N. 63° W | 3.7 | N. 54° W | 3.0 |
| 750 | S. 21° W | 12.4 | S. 9° W | 6.5 | S. 25° W | 5.0 | S. 54° W | 4.0 | N. 73° W | 4.2 | N. 53° W | 3.0 |
| 1,000 | S. 27° W | 12.8 | S. 14° W | 6.8 | S. 42° W | 5.0 | S. 66° W | 4.6 | N. 74° W | 5.2 | N. 50° W | 4.3 |
| 1,250 | S. 31° W | 12.4 | S. 14° W | 7.0 | S. 51° W | 5.6 | S. 72° W | 5.1 | | | | |
| 1,500 | S. 32° W | 11.3 | S. 16° W | 6.5 | S. 59° W | 6.5 | S. 80° W | 5.2 | N. 85° W | 6.7 | N. 57° W | 6.0 |
| 2,000 | S. 38° W | 9.6 | S. 17° W | 6.0 | S. 61° W | 8.9 | S. 83° W | 7.5 | S. 84° W | 10.0 | N. 70° W | 7.3 |
| 2,500 | S. 52° W | 6.8 | S. 15° W | 5.3 | S. 69° W | 13.7 | S. 81° W | 9.6 | S. 81° W | 11.0 | N. 72° W | 6.2 |
| 3,000 | S. 80° W | 6.6 | S. 16° W | 5.2 | S. 63° W | 15.2 | S. 84° W | 11.1 | S. 84° W | 11.2 | N. 82° W | 8.9 |
| 3,500 | | | | | S. 60° W | 15.9 | S. 82° W | 11.5 | S. 84° W | 11.5 | N. 74° W | 9.3 |
| 4,000 | | | | | S. 50° W | 10.1 | N. 89° W | 11.7 | S. 83° W | 10.3 | N. 70° W | 9.9 |
| 4,500 | | | | | S. 59° W | 10.9 | N. 80° W | 10.0 | N. 84° W | 10.2 | N. 68° W | 9.8 |
| 5,000 | | | | | | | | | N. 83° W | 11.0 | N. 68° W | 9.6 |

# WEATHER IN THE UNITED STATES

## THE WEATHER ELEMENTS

By P. C. DAY

### GENERAL CONDITIONS

The weather of June, 1928, in the United States was notable in several respects:

The average atmospheric pressure was on the whole unusually low, though individual cyclones were without decidedly deep centers; the average temperature was likewise unusually low, particularly over the eastern two-thirds, the month being the coolest of record for June in a few instances and much similar to June, 1927, another unusually cool month. Rainfall was frequent and at times unusually heavy over the eastern two-thirds of the country; many localities had monthly amounts far above the normal for June, a number had amounts in excess of those for any previous June, and a few in excess of the greatest previously reported in any month; while the number of rainy days and amounts of cloudiness were in many instances equal to or in excess of those for any previous June. On the other hand, a few sections of the far Southwest had almost continuous sunshine, though the temperatures were not unseasonably high.

### PRESSURE AND WINDS

While cyclonic conditions persisted with unusual frequency throughout the month over central and eastern districts, the barometric depressions were rather weak and confined to fairly short paths, but precipitation was frequently heavy over large areas.

A depression that appeared over the southern Rocky Mountains on the morning of the 3d became of considerable importance within the following 24 hours and during the 5th and 6th extended its influence over nearly all districts from the Mississippi River eastward. Heavy rains attended this depression in the Gulf and Atlantic Coast States, nearly 10 inches falling at Montgomery, Ala., during the 3d to 6th, and even larger amounts at some other points in that locality.

A cyclone of only moderate strength, passing eastward over the Northern States from the Dakotas to the Great Lakes and New England from the 7th to 10th, with an extension southward into the Mississippi Valley, brought widespread rains in portions of the Central and Northern States of the area covered, with heavy falls in a few localities.

On the morning of the 11th low pressure developed over the central Rocky Mountain region and during the following 48 hours passed to the northward of the Great Lakes attended by important precipitation over many portions of the central valleys and even into the Gulf States.

During the latter part of the second decade and the early part of the third a series of low-pressure areas passed over the central valleys, usually advancing northeast-

ward, and widespread rains, frequently of the thunderstorm type attended by hail and wind, were of frequent occurrence over wide areas.

The last few days of the month brought important precipitation from the middle plains eastward to the Atlantic coast, heavy falls occurring locally in the lower Missouri, middle Mississippi and Ohio Valleys.

Anticyclones were unimportant and mainly had little influence on the weather of the month, the generally cool conditions being largely due to unusual cloudiness lowering the daytime temperatures.

Local storms of more or less violent nature prevailed in all periods of the month and occurred at some time locally in nearly all parts of the country from the Rocky Mountains eastward, though most numerous in the eastern Great Plains and Mississippi Valley where heavy damage resulted locally.

A list of the more important storms of the month, with details as to loss of life, damage to property, etc., appears as usual at the end of this section.

The general distribution of the average monthly atmospheric pressure and prevailing directions of the winds appear on Chart VI and the departures from the monthly normals and changes from the preceding month on the insets to Charts II and III.

### TEMPERATURE

While the temperatures were mainly continuously low for June, there were no important cold periods and no serious damage to vegetation resulted therefrom save that progress was materially delayed and most crops were appreciably later than usual at the close of the month. At a number of points the average daily temperatures save on one or two dates did not rise above normal during the entire month. This was particularly the case with regard to the daytime temperatures which did not rise to the usual extent due to frequent cloudy and rainy conditions.

The several weeks of the month were uniformly cooler than normal over nearly all central and northern districts and the month as a whole had deficient temperature in all parts of the country save for local small excesses along the south Atlantic coast, from central Texas westward to southern California, and locally in the Pacific Coast States. Over the Missouri, Mississippi, and Ohio Valleys the average temperatures ranged from 2° to 6° below normal, a few points in this general region having the lowest June temperatures of record. Elsewhere the averages were moderately deficient, save as indicated above.

The highest temperatures of the month were experienced mainly during the middle part of the first decade over the Southwestern States, about the middle of the month over the North Atlantic States, from the 18th to 21st in the Ohio Valley and Gulf States and near-by areas, and during the closing half of the third decade over the Northwest. The maximum temperature on the 21st at Charlotte, N. C., 98°, was the highest recorded at that place during June in more than 50 years.

The highest reported temperature was 120° in southern California and maximum temperatures above 100° were reported from localities in most of the Southern States and in the lower elevations from the Rocky Mountains westward. Over a few States in the Lake region the temperatures did not rise as high as 90° at any time.

The lowest temperatures were experienced mainly during the first decade from Washington and Oregon east and southeast to the Atlantic coast, save in the Northeastern States, where they occurred in the first few days of the second decade, during which time the minimum temperatures were reported also from the Southwest.

Freezing temperatures occurred at exposed points in the Mountain States, the lowest reported, 17°, occurring in the mountains of Colorado, and temperatures were below 32° at exposed points in all the Western Mountain States and along the entire northern border.

### PRECIPITATION

As stated elsewhere, June was a remarkably wet month over practically all parts of the country from the Rocky Mountains eastward, all States in this area, save Minnesota, having averages above the normal. For most States from the Plains eastward to the Appalachian Mountains and in the lower Mississippi Valley the average monthly amounts were far in excess of the normal, in some cases more than twice as much, and individual localities had frequently three or four times the station normal.

The precipitation was rather uniformly distributed during the various portions of the month over nearly the entire area referred to above, so that no important crop areas suffered from lack of soil moisture though many had far too much, which greatly interfered with planting, germination, and cultivation.

The greatest fall for the month was 22 inches at Jackson, Mo., more than five times the June normal for the station, and amounts from 15 to 20 inches were reported from numerous stations in the States of heaviest precipitation.

Quite reverse conditions were reported from the Pacific Coast States and from central Texas westward, where the monthly precipitation in practically all sections was less than normal, though June is a month with usually light precipitation in all parts of this area.

### SNOWFALL

As is usual in June, snow was confined mainly to the higher elevations in the western Mountain States and only scattered amounts were reported from these. The heaviest fall reported was 20 inches in Wyoming, and amounts up to 12 inches were measured in Colorado, in the Yellowstone Park region, and in near-by areas of western Montana, and locally in Nevada. No measurable snow was reported from the Lake region or from the mountains of New York or New England.

### RELATIVE HUMIDITY

Despite the general coolness of the month, the frequency of precipitation, and the general resulting cloudiness, the average percentages of relative humidity were not materially higher than usual save in a few localities, mainly in the upper Missouri Valley where they ranged from 6 to 12 per cent above normal, and from the Ohio Valley to New England where they were from 5 to 10 per cent above. West of the Rocky Mountains and from central Texas to Arizona the relative humidity was generally less than normal, but the departures were usually unimportant save in extreme western Texas.

The general absence of extremely low humidity in the forest regions of the West greatly reduced the hazard of forest fires which were comparatively infrequent.

### SUNSHINE AND CLOUDINESS

In the Great Valley of California and the near-by areas of Arizona and other parts of the far Southwest the percentages of sunshine were high, reaching practically 100 at many points. Otherwise sunshine was usually distinctly less than normal, averaging not more than 20 to 30 per cent of the possible over large areas in the Ohio Valley and near-by areas and ranging up to 30 or 40 per cent in many sections from the Missouri Valley eastward to New England and in the central portions of the Gulf States.

## SEVERE LOCAL STORMS, JUNE, 1928

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

| Place | Date | Time | Width of path (yards) | Loss of life | Value of property destroyed | Character of storm | Remarks | Authority |
|---|---|---|---|---|---|---|---|---|
| Quay, N. Mex | 1 | 5-6.30 p.m. | | | $10,000 | Heavy hail | Much damage to crops, roads, buildings, etc | Official, U. S. Weather Bureau. |
| Algoma, Miss. (near) | 3 | Noon | | | | Probably tornado | Some damage to buildings; 8 persons injured | Do. |
| Trementina, N. Mex | 3 | 4 p. m. | [1] 6 | | | Heavy hail | All crops badly injured; some livestock killed | Do. |
| Jean, Olney, and Jermyn, Tex. | 3 | 8.15 p. m. | | | 1,000,000 | Wind | Heavy damage to property of every kind | Do. |
| Raton, N. Mex | 3 | P. m. | | | 2,400 | Hail and wind | Trees, gardens, and buildings injured | Do. |
| Marshall and Bedford Counties, Tenn. | 3 | | | | 5,000 | Small tornado | Character of damage not reported | Do. |
| Phillips County, Kans | 5 | 6 p. m. | 3,520 | | 100,000 | Hail and wind | Severe damage to crops and buildings over path 20 miles long. | Do. |
| Sterling, Nebr | 5 | 6.30 p. m. | 2,640 | | | Hail | Wheat damaged 50 to 75 per cent; path 8 miles | Do. |
| Zurich, Kans. (near) | 5 | do | 300 | | 600 | Tornado | Damage chiefly to farm buildings and implements. | Do. |
| Plainville, Kans. (near) | 5 | 7.30 p. m. | 300 | | 800 | do | do | Do. |
| Barton and Rice Counties, Kans. | 5 | 9 p. m. | [1] 3 | | 100,000 | Hail | Growing wheat totally destroyed in places; path 20 miles. | Do. |
| Milledgeville, Ga | 5 | P. m. | | | 25,000 | Small tornado | Several buildings unroofed; trees blown down | Do. |
| Luverne, Ala. (12 miles north of). | 5 | | | 1 | 30,000 | Severe thunderstorm. | Considerable property damage reported; 2 persons injured. | Do. |
| Nyssa, Oreg., to Weiser, Idaho. | 5 | P. m. | | | | Electrical and wind. | Extensive damage to trees, buildings, orchards, crops, and telephone lines. | Do. |
| London, Ohio | 6 | | | | | Probably tornado | No details reported | Do. |
| Union County, Iowa | 7 | 5-6 p. m. | | | 15,000 | Wind and hail | Crops injured; buildings damaged | Do. |
| Oklaunion and Vernon, Tex. | 7 | 8.30-9 p. m. | [1] 1-2 | | 175,000 | Wind | Crops and buildings severely damaged; 1 person hurt. | Do. |
| Adair County, Iowa | 7 | 11.30 p. m. | | | | Hail | Severe crop damage | Do. |
| Elkader to Oakley (25 miles south of), Kans. | 7 | P. m. | | | 5,000 | Tornado | Character of damage not reported | Do. |
| Benton, Keokuk, Lucas and Wayne Counties, Iowa. | 7 | | | | | Wind | Buildings and crops considerably damaged | Do. |
| Clark County, Kans. (northern). | 7-8 | | [1] 5 | | 1,000,000 | Hail | Damage chiefly to growing wheat over path 15 miles long. | Do. |
| McPherson and Harvey Counties, Kans. | 7-8 | | [1] 10 | | 1,000,000 | Wind and hail | Extensive damage to growing wheat; path 25 miles. | Do. |
| Fort Scott (near) to Crowsburg, Kans. | 8 | 3 a. m. | | | 5,000 | Tornado | Buildings damaged | Do. |
| Campo, Colo | 8 | 4 p. m. | 1,000 | 2 | 11,000 | do | Six farm buildings destroyed; crops damaged; 6 persons injured. | Do. |
| Greeley, Wichita, Kearney, Gray, and Ford Counties, Kans. | 8 | 5.30-10.30 p. m. | [1] 4-20 | | 3,000,000 | Hail | Crop loss heavy and other property damaged over path 100 miles long. | Do. |
| Harper and Sumner Counties, Kans. | 8 | 10 p. m. | [1] 10 | | 100,000 | High winds | Severe property damage in Caldwell and Waldron. | Do. |
| Arriba, Colo | 8 | | 1,700 | | 5,000 | Hail | Character of damage not reported | Do. |
| Garden City, Kans. (near) | 8 | | | | 1,000 | Tornado | One residence demolished; farm buildings damaged. | Do. |
| Ontonagon County, Mich | 8 | | | | | Small tornado | No details reported | Do. |
| Cowley County, Kans | 9 | 2 a. m. | 880 | | 25,000 | Hail and wind | Much window glass broken; other property damage. | Do. |
| Bolling Field and Hains Point, Washington, D. C. | 9 | 4.15 p. m. | 100 | 1 | 100,000 | Severe thunder squall. | 12 planes wrecked; hangars and other property damaged; 115 trees uprooted; 6 persons injured. | Do. |
| Recona, N. Mex | 9 | 4-5 p. m. | [1] 6 | | | Hail | Crops badly damaged on a number of farms | Do. |
| Somerset County, Md (western). | 9 | 10.30 p. m. | | | 100,000 | Severe thunderstorm, probably tornado. | 35 buildings wrecked or damaged; trees uprooted; 10 persons injured. | Do. |
| Mexia, Tex | 9 | 11 p. m. | | | | Hail and wind | Crops and buildings severely damaged | Do. |
| Baltimore, County, Md | 9 | | | | 32,000 | Wind and hail | 8 houses unroofed; homes, autos, and wires damaged in Baltimore city; other damages in vicinity. | Do. |
| Daviess County, Ind | 9 | | | | 50,000 | Hail | Heavy crop damage | Do. |
| Vestal, N. Y. (near) | 9 | | | | | Probably small tornado. | A barn and small outbuildings demolished; 1 house damaged. | Do. |
| Rotan, Tex. (near) | 10 | 9 p. m. | | | 15,000 | Wind | Crops and buildings damaged | Do. |
| Lower Twist Valley, Okanogan County, Wash. | 11 | 11 a. m. | | | | Hail | Commercial apple crop badly damaged | Do. |
| Cherry County, Nebr. (western). | 11 | 7 p. m. | 100 | | 1,500 | Tornado | A number of buildings wrecked; large trees uprooted; path 35 miles. | Do. |
| Ludell, Kans., to McCook, Nebr. | 11 | 7.30 p. m. | 300 | | | do | Heavy damage in McCook; many farm buildings damaged; path 75 miles. | Do. |
| Oakley, Kans. (near) | 11 | 7.30 p. m. | 300 | | 12,000 | do | Farm buildin damgsaged; path 27 miles | Do. |
| Lyon and Osceola Counties, Iowa. | 11 | | | | | Wind | Telephones, trees, and buildings damaged | Do. |
| Kearney, Nebr | 12 | 12.30 a. m. | 130 | | 18,000 | do | 2 large barns demolished; small outbuildings, trees, and telephone poles damaged. | Do. |
| Woods County, Okla. (northern). | 12 | do | [1] 3-6 | | 200,000 | Hail and wind | Extensive crop injury; other property damage considerable. | Do. |
| Lyon County, Iowa | 12 | 3 a. m. | | | 3,000 | Tornado | Character of damage not reported | Do. |
| Waterloo, Nebr | 12 | 3-4 a. m. | | | 12,000 | Wind | A barn and several buildings wrecked | Do. |
| Beatrice, Nebr | 12 | 3.30 a. m. | 160 | | 3,000 | Tornado | A number of farm buildings demolished; path 880 yards long. | Do. |
| Woodbury County, Iowa | 12 | do | | | | do | Buildings damaged; poultry killed | Do. |
| Cass County, Iowa | 12 | 5 a. m. | | | 2,500 | do | Character of damage not reported | Do. |
| Hamilton County, Iowa | 12 | 7 a. m. | | | 500 | do | Minor property damage | Do. |
| Louisa County, Iowa | 12 | do | | | | do | Buildings damaged; poultry injured | Do. |
| Cheyenne County, Nebr. (eastern). | 12 | 3 p. m. | | | 12,000 | do | Number of buildings wrecked | Do. |
| Seward County, Kans | 12 | 3-4 p. m. | [1] 30 | | 1,000,000 | Hail | Growing wheat severely damaged | Do. |
| Grundy County, Iowa | 12 | 7.30 p. m. | | | | Tornado | Buildings damaged; stock injured | Do. |
| Bates to Cauthron, Ark | 12 | | 100 | 2 | 10,000 | do | Considerable property damage over path 12 miles long. | Do. |
| Cedar, Cherokee, Dubuque, Mitchell, Page, Pottawattamie, and Wayne Counties, Iowa. | 12 | | | | | Wind | Buildings, trees, crops, and overhead wires damaged; stock injured. | Do. |
| Hillside, Erie, and vicinity, Ill. | 12 | | 50-440 | | 2,500 | Tornado | Monuments blown over; silos and windmills wrecked; path 12 miles. | Do. |
| Moline, Rock Island, and vicinity, Ill. | 12 | | | | 5,000 | High winds | Loss principally to telephone and electric power companies. | Do. |
| Wichita, Kans. (near) | 12 | P. m. | | | | Tornado | Slight damage as storm passed over open country. | Do. |

[1] Miles.

*Severe local storms, June, 1928*—Continued

| Place | Date | Time | Width of path (yards) | Loss of life | Value of property destroyed | Character of storm | Remarks | Authority |
|---|---|---|---|---|---|---|---|---|
| Omak, Wash. (near) | 13 | 3. p. m. | 880 | | $75,000 | Hail | Commerical apple crop badly damaged | Official, U. S. Weather Bureau. |
| Wild Rose, Wis | 13 | 3.30 p. m. | | | | Severe squall | Several buildings unroofed; other minor damage. | Do. |
| Selah, Wash. (near) | 14 | 4-5 p. m. | [1] 1-3 | | 300,000 | Hail | About 1,500 cars of apples damaged; also cherries and gardens; path 8 miles. | Do. |
| Pratt, Barber, and Harper Counties, Kans. | 14 | 5-6 p. m. | [1] 6 | | 1,400,000 | do | Damage chiefly to wheat; path 70 miles | Do. |
| Morton, Seward, and Stevens Counties, Kans. | 14 | 9 p. m. | [1] 10 | | 100,000 | do | Damage chiefly to wheat; path 40 miles | Do. |
| Haxtun, Colo | 15 | 8-9 p. m. | [1] 8 | | 300,000 | do | Crops severely damaged | Do. |
| Akron, Colo. (near) | 15 | 11 p. m. | 200 | | 3,000 | Tornado | Farm buildings destroyed; stock killed | Do. |
| Keota to Willard, Colo | 16 | 5-6 p. m. | [1] 3-6 | | | Hail | Character of damage not reported | Do. |
| Rush County, Kans. (southern). | 16 | 5.30 p. m. | 16 | | 5,000 | Tornado | Some damage to property in rural districts; path 15 miles. | Do. |
| Brookville, Kans. (near) | 16 | 6 p. m. | 33-440 | | 51,000 | do | Homes, farm buildings, machinery damaged; livestock and poultry killed or injured; path 8 miles. | Do. |
| Solomon, Kans. (near) | 16 | do | 33 | | 3,000 | do | Farm buildings demolished; path 5 miles | Do. |
| Greensburg to Sawyer, Kans. | 16 | 6-8 p. m. | 100-880 | | 150,000 | Tornado and hail | Overhead wires, trees and houses blown down; roofs and machinery damaged; crops beaten; 2 persons injured; path 40 miles. | Official, U. S. Weather Bureau. Pratt Daily Tribune (Pratt, Kans.). |
| Alden, Kans. (near) | 16 | 6.30 p. m. | 33 | | 1,500 | Tornado | Slight damage in rural districts; path 3 miles | Official, U. S. Weather Bureau. |
| Falun, Kans. (near) | 16 | do | 16 | | 1,000 | do | Character of damage not reported | Do. |
| Lincoln, Colo | 16 | 7 p. m. | | | 115,000 | Hail | Details of damage not reported | Do. |
| Stafford, Kans. (near) | 16 | do | 880 | | 10,000 | Tornado | Considerable damage to property in rural districts; 1 person injured. | Do. |
| Arlington, Kans | 16 | 7.45 p. m. | | | 2,500 | Wind | Business section of town damaged | Do. |
| Thurman, Colo. (near) | 16 | 8.30 p. m. | 880 | | 2,500 | Tornado | Farm buildings wrecked; stock killed | Do. |
| Blair to Holliday, Okla | 16 | P. m. | | 3 | | do | More than 2,000 persons made homeless; loss of farm property, crops, and livestock enormous. | Do. |
| Boone and Crawford Counties, Iowa. | 16 | | | | | Wind and rain | Overhead wires and trees damaged | Do. |
| Americus, Kans. (near) | 17 | 3 p. m. | 200 | | 78,000 | Tornado | Farm buildings demolished; 1 person injured; path 1.5 miles. | Do. |
| Bovina, Colo. (near) | 17 | 6 p. m. | [1] 5-8 | | | Hail | Crops total loss | Do. |
| Chanute, Kans. (near) | 17 | do | 300 | | 20,000 | Tornado | Farm buildings, a church, and a schoolhouse demolished; path 12 miles. | Do. |
| Arriba, Colo | 17 | 7 p. m. | [1] 7 | | | Hail | Character of damage not reported | Do. |
| Grafton, Ill | 17 | 8.45 p. m. | | | 20,000 | Wind | Light buildings and a warehouse destroyed; several homes damaged. | Do. |
| Arickaree, Colo | 17 | 10 p. m. | 1,760 | | | Hail | Crops damaged 50 to 75 per cent | Do. |
| Vona, Colo | 17 | P. m. | | | | 3 hail storms | Crop loss about 50 per cent | Do. |
| Stratton, Colo | 17 | | [1] 6 | | | do | Stones very large, buildings damaged; hogs killed. | Do. |
| Wisconsin (southwestern) | 17-18 | | | | | Severe thunderstorms. | Some damage by lightning; basements and streets flooded. | Do. |
| Washita County, Okla. (western). | 18 | 4 p. m. | [1] 10 | | 800,000 | Hail | Small animals killed; stock bruised; total crop loss in much of area; other property damage; path 20 miles. | Do. |
| Rosendale, Mo. (near) | 18 | 6.30 p. m. | 50-130 | | | Tornado | No damage reported | Do. |
| Adams County, Iowa | 18 | 7.30 p. m. | [1] 4 | | 125,000 | Tornado and hail | Extensive property damage | Do. |
| Pattonsburg, Mo | 18 | 8 p. m. | | | 150,000 | Tornadic wind | Dwellings, barns, and other structures demolished; stock injured. | Do. |
| Union County, Iowa | 18 | do | | | 10,000 | Tornado | Details not reported | Do. |
| Franklin, Ky. (near) | 18 | | | | | Wind | Houses and barns unroofed | Do. |
| Franklin to Washington County, Ohio. | 18 | | | 2 | 1,000,000 | Tornado | Extensive property damage | Do. |
| Fort Branch, Ind | 18 | | | | 25,000 | Tornadic wind | Considerable property damage | Do. |
| Johnson County, Ill. (southern). | 18 | | [1] 10 | | 50,000 | Wind | Light buildings and houses moved from foundations; windows broken; path 15 miles; 10 injured. | Do. |
| Kirkland, Ill | 18 | | | | 50,000 | Electrical | Large grain elevator burned | Do. |
| New Point, Mo | 18 | | 100 | 1 | 50,000 | Tornado | Buildings, household effects, etc., damaged over path 6 miles long; 2 persons injured. | Do. |
| Grant County, Okla. (central). | 19 | 3.30 p. m. | [1] 3 | | 50,000 | Hail | Damage chiefly to crops; path 8 miles | Do. |
| Wolsey, S. Dak | 19 | 4 p. m. | | | 30,000 | do | Crops ruined | Do. |
| Garretson, S. Dak | 19 | 5 p. m. | 2,000 | | 15,000 | do | do | Do. |
| Grundy County, Iowa | 19 | 6 p. m. | [1] 2 | | 20,000 | do | Crops damaged; path 3 miles | Do. |
| Johnson, Kans., and vicinity. | 19 | 8.30 p. m. | | | 5,000 | Tornado | Many building damaged over path 7 miles long | Do. |
| Clinton County, Ohio | 19 | | | | 50,000 | do | Considerable property damage reported | Do. |
| Richmond, Va | 19 | P. m. | | | 3,000 | Thunderstorm | Number of buildings unroofed; trees uprooted | Do. |
| Wayne and Henry Counties, Ind. | 19 | | | | | Thunderstorms | Much damage to crops and other property | Do. |
| Crowley, Otero, and Pueblo Counties, Colo. | 19-20 | P. m. | [1] 2-7 | | 2,000,000 | Hail and floods | Some crops a total loss; much damage to buildings by flooding; trees uprooted; small houses wrecked. | Do. |
| Stanton, Morton, Grant, Haskell, Seward, Meade, and Clark Counties, Kans. | 19-20 | 11 p. m.-2 a. m. | [1] 10-30 | | 3,000,000 | Hail | One of the worst storms in history of State; wheat damaged 50 to 100 per cent; path 140 miles. | Do. |
| Harper County, Okla. (northern). | 20 | 12.05 a. m. | | | 850,000 | Heavy hail | Severe crop loss; other property damage considerable. | Do. |
| Woods County, Okla | 20 | do | [1] 5 | | 78,000 | do | Crops devastated; path 40 miles | Do. |
| Pierce County, Wis. (Big River Valley). | 20 | 1.30-2 p. m. | 4 | | 35,000 | Tornado and hail | Farm buildings and crops damaged; stock injured; path 4 miles. | Do. |
| Trempealeau County, Wis. (central). | 20 | 5 p. m. | [1] 5 | | 10,000 | Hail | Damage chiefly to growing corn and tobacco | Do. |
| Ness and Pawnee Counties, Kans. | 20 | 5-6 p. m. | [1] 1-12 | | 200,000 | do | Damage chiefly to growing wheat; path 65 miles | Do. |
| Kenton through Boise City, Okla., into Texas. | 20 | 7.25-7.43 p. m. | [1] 2-7 | | 510,000 | Heavy hail | Crops devastated; other property damaged; path, 40 miles. | Do. |
| Elm Island, Nebr | 20 | 7.30 p. m. | 1,320 | | | Hail | Crops damaged; many gardens ruined | Do. |
| Ravenna, Nebr | 20 | 9-10 p. m. | 1,760 | | 10,000 | do | Crops damaged about 30 per cent; path 3 miles | Do. |
| Clay County, Nebr. (southern). | 20 | 11.30 p. m. | [1] 4 | | 360,000 | Hail and wind | Crops a total loss in places; 50 to 75 per cent in others; path 25 miles long. | Do. |
| Lyman, Nebr | 21 | 2.30 p. m. | | | 15,000 | Hail | Crops considerably damaged | Do. |
| Garden County, Nebr | 21 | 5 p. m. | [1] 8 | | 150,000 | Heavy hail | Damage to crops from slight injury to total loss over path 15 miles long. | Do. |
| Piqua, Ohio | 21 | P. m. | | | | Tornado | No details reported | Do. |
| Des Moines, Iowa, and vicinity. | 21 | | | | | Wind and hail | Buildings and crops damaged | Do. |
| Washington County, Iowa | 22 | 10.30 a. m. | | | 2,000 | Tornado | Minor property damage | Do. |

[1] Miles.

*Severe local storms, June, 1928*—Continued

| Place | Date | Time | Width of path (yards) | Loss of life | Value of property destroyed | Character of storm | Remarks | Authority |
|---|---|---|---|---|---|---|---|---|
| Sherman County, Kans. (southern). | 22 | 2 p. m. | [1] 1-2 | | 100,000 | Hail | Chief damage to wheat; path 15 miles. | Official, U. S. Weather Bureau. |
| Lyman, Nebr. | 22 | 4 p. m. | | | 15,000 | do | Crops damaged. | Do. |
| Spokane (near) and Sumner, Wash. | 22 | P. m. | | | | do | Severe damage to commercial orchards and raspberry fields. | Do. |
| Garnett, Kans. | 22 | | | | | Tornado | No details reported. | Do. |
| Van Zandt County, Tex. | 23 | 12.30 a. m. | [1] 6 | | 105,000 | Wind and hail | Extensive damage to crops and buildings over path 30 miles long. | Do. |
| Pawnee County, Nebr. (southwestern). | 23 | 3 a. m. | | | 25,000 | Hail | Much crop damage in places. | Do. |
| Gotebo, Okla. | 23 | 5 a. m. | [1] 5 | | 65,000 | do | Practically all buildings damaged to some extent; crops loss heavy. | Do. |
| Gove County, Kans. (southwestern). | 23 | Near noon. | 14 | | | Tornado | Minor damage. | Do. |
| Nuckolls County, Nebr. (central and southwestern). | 23 | 1 p. m. | [1] 8 | | 300,000 | Hail and rain | Heavy crop damage; livestock injured, windows broken; path 8 miles. | Do. |
| Republic and Cloud Counties, Kans. | 23 | 2-3 p. m. | [1] 3-6 | | 275,000 | Heavy hail | Greatest loss to wheat; path 43 miles. | Do. |
| Cedar (northeast) and Dixon (northwest) Counties, Nebr. | 23 | 3 p. m. | | | 10,000 | Tornado | Farm buildings wrecked; 1 person injured; path 7 miles. | Do. |
| Kettle Falls, Wash. | 23 | do | | | 10,000 | Hail | Apple crops, gardens and windows damaged. | Do. |
| Colfax County, Nebr. | 23 | 4-5 p. m. | [1] 2 | | 20,000 | do | Crops damaged; windows broken; path 12 miles. | Do. |
| Webster County, Nebr. (northern). | 23 | 5-6 p. m. | [1] 2 | | 25,000 | do | Crops damaged 50 per cent in places; path 15 miles. | Do. |
| Arlington, Kans. | 23 | 7 p. m. | 8-440 | | | Tornado | Property damage comparatively small. | Do. |
| Clovis, N. Mex. | 23 | P. m. | | | | Heavy hail | Heavy damage to wheat, buildings, etc. | Do. |
| Webb City, Okla. | 24 | 2.30 a. m. | | | 31,000 | do | Crops damaged. | Do. |
| Trementina, N. Mex. | 24 | 3 p. m. | | | | Hail | Crops considerably beaten. | Do. |
| Haxtun and Dailey, Colo. | 25 | 2.30 p. m. | [1] 6 | | 400,000 | do | Severe property damage over 30-mile path. | Do. |
| Carnegie, Okla. | 25 | 4.30 p. m. | | | 25,000 | do | Crops damaged. | Do. |
| Newville and Blosserville, Pa. | 25 | | | | | Wind | Several buildings damaged or destroyed; trees uprooted; crops beaten. | Do. |
| Midwest, Wyo. | 26 | 4.15 p. m. | 150 | | 300,000 | Tornado | Many buildings and derricks wrecked; crops injured; 8 persons hurt. | Do. |
| Shawnee, Wyo. | 26 | 5 p. m. | [1] 9 | | 5,000 | Wind and hail | Buildings and crops damaged. | Do. |
| Jefferson County, Nebr. (western). | 26 | 6.30-7 p. m. | 1,760 | | 6,000 | Hail | Wheat and oats damaged 20 to 80 per cent in places; path 8 miles. | Do. |
| Torrington, Wyo. | 26 | 6.30 p. m. | [1] 4 | | 17,000 | Wind and hail | Crops and buildings damaged. | Do. |
| Friona, Tex. | 26 | 10 p. m. | [1] 8 | | 75,000 | Hail | do | Do. |
| Wichita Falls, Tex. (near) | 27 | 2 a. m. | 880 | 1 | 5,000 | Hail and wind | Farm property damaged; 2 persons injured. | Do. |
| Wessington, S. Dak. | 27 | P. m. | 30 | | 500 | Tornado | Small damage to farm property. | Do. |
| Keokuk County, Iowa. | 28 | 1.30 p. m. | | | 7,500 | do | Details not reported. | Do. |
| Lucas County, Iowa. | 28 | 4 p. m. | | | 3,000 | do | do | Do. |
| Limon, Colo. | 28 | 7.15 p. m. | [1] 2 | | 25,000 | Hail | do | Do. |
| Bumpus Mills, Rutherford, Md., and Southside, Tenn. | 28 | P. m. | | | 40,000 | Tornadic winds | Much property damage reported; 19 persons injured. | Do. |
| Des Moines County, Iowa. | 28 | | | | 30,000 | Wind, hail and flood. | Considerable property damage. | Do. |
| Nashville, Tenn. (near) | 29 | 1 a. m. | | 1 | 50,000 | 2 tornadic windstorms. | A number of buildings damaged or totally wrecked; many trees uprooted; telephone service crippled. | Do. |
| Alexandria, Tenn. | 29 | 2 a. m. | | | 100,000 | Tornadic wind | Extensive property and crop damage. | Do. |
| Johnstown, Colo. (near) | 29 | 12.30 p. m. | 500 | 3 | 250,000 | Tornado | Farm buildings and equipment wrecked; livestock killed; crops ruined; 50 persons injured. | Do. |
| Gillette, Wyo. (near) | 29 | 1.45 p. m. | 67 | | 2,000 | do | Buildings and crops damaged; livestock injured. | Do. |
| Easley, S. C. | 29 | 9.30 p. m. | 200 | | 60,000 | do | 25 or 30 houses damaged; 2 persons injured. | Do. |
| El Paso, Elbert, and Lincoln Counties, Colo. | 29 | P. m. | | | | Hail and rain | Severe crop loss; soil badly washed in places. | Do. |
| Spartanburg County, S. C. | 29 | do | 200 | | 150,000 | Wind and rain | Dwellings, outhouses, crops, and trees badly damaged. | Do. |
| Riverton, Wyo. | 29 | | | | 5,800 | Hail | Crops damaged over small area. | Do. |

[1] Miles.

## RIVERS AND FLOODS

By H. C. FRANKENFIELD

In general, June was a month of unusually heavy rainfall east of the 100th meridian, and as a result floods of some kind occurred over all that section of the country except New England and the Middle Atlantic States. As a rule the floods were of moderate character, and only in the Grand River of Missouri, the White and Black Rivers of Missouri and Arkansas, and the lower Neosho and Verdigris Rivers of Kansas and Oklahoma did they attain more than fair proportions. However, the aggregate damage was much greater than would be supposed at first thought—both on account of the large acreage of crop lands overflowed and of the numerous washouts and overflows of quite small streams.

*Atlantic drainage.*—Only local floods in the lower Santee River of South Carolina during the first decade of the month, and in the Broad River of the same State on the last day. Previous high waters had left the swamp floors in a very soggy condition and consequently there was little or no movement of livestock and therefore no losses.

*East Gulf drainage.*—During June 3, 4, and 5, rainfall over the Tallapoosa, Cahaba, and Alabama River drainage areas ranged from 2.75 to 9.50 inches, Montgomery, Ala., reporting 7.34 and Selma, Ala., 6.10 inches during the 24 hours ending 8 a. m. June 5. Warnings were first sent during the afternoon of June 4 for the Tallapoosa River and on the following morning for the Cahaba and Alabama Rivers. Owing to the frequent manipulation of the gates of the various power plant dams above, accurate forecasts for the Alabama River were not possible until the morning of June 6. Flood stages were not reached on the Coosa River. Losses and damage reported were as follows:

| | |
|---|---|
| Miscellaneous | $66, 450 |
| Crops, matured | 11, 400 |
| Crops, prospective (19,420 acres) | 154, 150 |
| Livestock, etc | 2, 400 |
| Suspension of business | 19, 025 |
| Total | 253, 425 |

Money value of property saved through Weather Bureau flood warnings, $89,100.

The excessive rains also covered the drainage basin of the lower Tombigbee River of Alabama, and rather severe

floods resulted from Demopolis, Ala., to the mouth of the river. At Demopolis the crest stage was 45.9 feet, 6.9 feet above the flood stage, and only very low bottoms were overflowed; but near the mouth of the river, where the rainfall had been heaviest, the water over some of the bottoms was nearly as high as in May, 1928, when the crest stage at Demopolis was 61.2 feet on May 1. Heavy rains on June 14 again brought the river to the flood stage at Demopolis, and for the third time during the month of June 28th, the river cresting at 42.3 feet on the morning of June 30, and falling below the flood stage on July 2.

Losses and damage amounted to $121,875, of which $96,000 was in prospective crops, while the reported value of property saved through the flood warnings was $42,510.

Over the Pascagoula and lower Pearl River systems of Mississippi the rainfall of early June was even greater than to the eastward, ranging from 5 to nearly 15 inches. The major portion of the rains centered in the 24 hours ending at 8 a. m. June 5, and the resulting floods did great damage to highways, bridges, and crops. Losses as reported were as follows:

| | |
|---|---|
| Bridges, highways, lumber, etc | $749, 000 |
| Crops, actual | 18, 000 |
| Crops, prospective | [1] 310, 000 |
| Livestock | 3, 600 |
| Suspension of business | 24, 000 |
| Total | 1, 104, 600 |

Value of property saved through warnings: $30,000, plus a large figure in livestock.

*Mississippi drainage.*—In the State of Ohio the month was, with the exception of June, 1902, the wettest June for 46 years, and but for the fact that it followed one of the driest Mays on record the resulting floods would certainly have been much more serious. As it happened the floods were not general, and those that did occur in the Hocking and lower Scioto Rivers were not very severe, although they caused the loss of one life and damage amounting to about $50,000, of which about 90 per cent was in crops in which 4,145 acres were involved. Warnings were issued as required, but no estimate could be made of benefits resulting therefrom.

A heavy two-day rain of nearly 3 inches on June 28 and 29 caused a great rise in Twelve Pole Creek, a small tributary of the Ohio River, and at 2 a. m. June 30 the creek at Wayne, W. Va., reached a stage of 28.3 feet, 3.3 feet above the flood stage, and the highest stage of which there is record. At the same time a rain of 5.50 inches at Lexington, Ky., brought the Town Branch, the local drainage brook, over its banks and into the streets of Lexington, covering the commercial section of Main Street to a depth of from 6 to 24 inches. The total damage amounted to more than $700,000, of which about $500,000 was in housed tobacco and $160,000 in hotel property.

A flood in Green and Big Barren Rivers of Kentucky was caused by a heavy two-day rain of 2 or 3 inches on June 8 and 9. While the stages were not unusually high the damage was very great owing to the inundation of from 50,000 to 75,000 acres of planted corn and tobacco, principally in Ohio, McLean, and Daviess Counties. The American Red Cross was called upon to furnish aid to several hundred families in seven counties, and the total losses were estimated at $2,000,000. Not much could be saved by warnings, only $27,500 having been reported.

There was a moderate flood in the West Fork of the White River of Indiana, causing damage amounting to about $77,000, of which $75,000 was in prospective crops. The total damage to prospective crops will far exceed these figures and will cover a much wider area, but it was due to standing water from downpours of rain collecting on the bottoms or washing slopes, and to overflows of small creeks.

The flood in the Cumberland River of Kentucky and Tennessee was caused by rains of 4.5 to 6.5 inches on June 28 and 29. At Burnside, Ky., the river rose 39.5 feet in two days, reaching a crest of 54 feet, 4 feet above the flood stage, during June 30. There were also proportionate rises below, and the total damage reported aggregated $1,208,500, of which $965,000 was in prospective crops. The money value of property saved through the warnings was $38,000.

The rainfall over the drainage area of the upper Tennessee River was no less severe, yet measured by actual stages of the rivers the floods were more moderate. However, the damage reached relatively enormous proportions on account of the huge losses in prospective crops as well as to the fields themselves. As usual, small creeks contributed greatly, and rough estimates of the damage were as much as $3,500,000, with little or no savings from warnings owing to the character of the damage.

Naturally, a general and decided rise was in progress in the Ohio River at the close of the month, but flood stages had not been reached at any place.

Heavy rains from June 20 to 22 caused a severe flood in the Salt River of northeastern Missouri, with a stage at New London on June 21 of 28 feet, 8 feet above the flood stage. There was considerable damage of the usual character, and traffic was interrupted for two days. The damage amounted to about $365,000, of which $150,000 was in prospective crops.

The flood in the Mississippi River below the mouth of the Missouri River was still in progress below the mouth of the Ohio River, and it will be discussed in the REVIEW for July, 1928. This report will include the very disastrous flood in the St. Francis River of Missouri and Arkansas.

With other States, Missouri was also very wet in June, with an excess of as much as 16 or 17 inches at some places. Illinois was also very wet, with an excess as high as 13 inches in places. The rains were well distributed, but in Missouri there were short periods of very heavy fall with resulting floods of which those in the small streams were the most destructive. As in other States, the greatest losses were in growing crops that no warnings could save, although many were issued. The statement of losses will be combined with those of July in the REVIEW for that month.

Eastern Kansas contributed a full measure to the flooded areas, and with very little variation as to causation, character, and ultimate results. Again the stages of water in the larger streams were not at all unusual, while the overflows of the small streams caused the most damage. The Osage River flood of June 1 and 2 inundated 4,000 acres of farm lands, causing losses in prospective crops of about $48,000, a comparatively small item when compared with $864,000 reported from the Neosho Basin. Of this large amount, $368,000 was in growing crops, $317,000 in matured crops, and $82,500 in livestock and other movable farm property. As usual under such circumstances, the savings through the flood warnings were small, only $25,000 having been reported.

[1] Very incomplete. Probably twice as much.

5021—28——3

Arkansas River floods within the State of Kansas were not of consequence, although overflows of smaller streams flooded several hundred acres of farm lands.

The Arkansas River was quite high much of the month below the Kansas line, with flood stages from Webbers Falls, Okla., to Morrilton, Ark., and moderate floods also occurred in the Verdigris and lower Neosho Rivers. Once more crops suffered greatly, 28,400 acres having been overflowed, with losses amounting to $300,000, of which $220,000 was in growing crops. Other losses reported amounted to $56,000. The reported value of property saved through the warnings was $40,000. It appears that in the State of Oklahoma the larger streams were directly responsible for the greater portion of the losses.

The floods in the White and Black Rivers of Arkansas were severe, with stages much above the flood line. The levee along White River just below Newport, Ark., broke, and 90,000 acres of land were inundated. The season was so late that much of the land can not be replanted, none at all to cotton, and the losses therefore in prospective crops alone will exceed $1,000,000. Levee losses were $123,000 and others about $155,000, making a total of approximately $1,278,000. Savings through warnings were given as $131,000.

Very heavy local rains centering on June 23 caused moderate floods in the Sulphur and Cypress Rivers of Texas, tributaries of the Red River. Losses as reported amounted to about $50,000, mostly in prospective crops, while the reported value of property saved through the warnings was $20,000.

There were unimportant floods in the Colorado River and in its tributaries within the State of Colorado, with only one loss of consequence, that of the new highway bridge across the Colorado River near Blythe, Calif., through the undermining of the piers. The loss was estimated at $100,000.

The following report on the annual rise of the Columbia River was prepared by Mr. Edward L. Wells, Meterologist in charge of the Weather Bureau office at Portland, Oreg.:

The 1928 rise of the Columbia River was unusual in several respects. The quantity of water passing down the river was less than in the high-water period in 1927, and the duration of high stages was less than in 1927 and not more than in an ordinary year, yet the crest of the rise, as shown by records of backwater in the Willamette at Portland, was the highest since 1894.

Information assembled at the close of the snow season, as of March 31, indicated that over the drainage basin of the Columbia River September, November, December, and March had been relatively wet, while October, January, and February were much drier. The soil was moist under the snow, and the snow supply was somewhat above normal, with the lower layers compact and the upper layers rather loose. Opinions differed somewhat as to whether the snow supply at the close of March was greater than at the close of the corresponding month in 1927. In marked contrast to the public attitude in 1927, there was very little local apprehension of a serious flood.

The snowfall bulletin issued after the close of March stated that with normal weather prevailing till early in June the crest at Portland should be between 20 and 22 feet.

April was unusually cool in the mountain area, and there was little metling of snow in the high mountains till near the close of the month; moreover, much new snow fell during the month. This cold April was followed by an abnormally hot May. Over much of the drainage basin of the Columbia River it was the warmest May in 30 years. There was a notable absence of the usual short periods of freezing nights in the mountain areas. The closing days of May were marked by a gerneral change to cooler weather, and temperature through most of June was subnormal.

These conditions resulted in a distinct shortening of the period of rapid melting, and materially increased the rate of melting in May. Consequently the crest of the rise at Portland was more than 2 feet above the extreme which had been expected if normal conditions had prevailed, and occurred 10 days in advance of the average date.

Actual forecasts of river stages, issued from day to day for three days in advance, were timely and accurate, permitting the saving of practically all movable property and obviating necessity of moving property which was not endangered.

On April 28, the stage at Portland being 8.6 feet, the public was advised that the annual rise had begun. At this time definite stage forecasts were inaugurated. On May 8 warning was issued for the flood stage of 15 feet by the 11th. This stage was reached at 5 a. m. on the 12th. On May 28 it was stated that the Willamette at Portland would come to a stand on the afternoon of the 30th at about 24.6 feet. The crest was 24.4 feet, reached at 3 a. m. on the 31st.

Following is an approximate statement of the losses caused by the flood:

| | |
|---|---|
| Tangible property | $27, 530 |
| Matured crops | 87, 300 |
| Prospective crops (including pasture) | 118, 875 |
| Livestock and other movable property | 340 |
| Suspension of business | 49, 235 |
| Moving goods, pumping, etc | 12, 571 |
| Total | 295, 851 |

Items on reports received indicate that property was saved by the warnings amounting to $443,650, but it is known that much property was saved which is not included in these items. It is not possible to get in touch with those who receive the warnings by radio or through the press, and even those who are communicated with and furnish reports often state that they saved all their property but do not place a value on it.

The floods of June, 1928, were notable in two respects: (1) in their wide distribution, indicating an unusually wet month, and (2) in the enormous amount of loss of prospective crops caused by overflows of quite small streams, the large streams contributing much the minor share.

The total reported losses of crops aggregated $9,033,725, of which $8,600,025 were in prospective crops, the States of Tennessee (eastern), Kentucky, Arkansas, Oklahoma (eastern), and Kansas (eastern) contributing nearly $7,000,000. These figures do not include losses within the State of Missouri which will be reported later.

[All dates in June except as otherwise specified]

| River and station | Flood stage | Above flood stages—dates | | Crest | |
|---|---|---|---|---|---|
| | | From— | To— | Stage | Date |
| ATLANTIC DRAINAGE | *Feet* | | | *Feet* | |
| Lackawaxen: Hawley, Pa | 9 | 30 | 30 | 10.0 | 30 |
| Santee: | | | | | |
| Rimini, S. C | 12 | (1) | 5 | 14.1 | May 30 |
| | | 9 | 10 | 12.3 | 9 |
| Ferguson, S. C | 12 | (1) | 3 | 13.4 | May 30 |
| | | 9 | 10 | 12.0 | 9-10 |
| Broad: Blairs, S. C | 15 | 30 | 30 | 15.8 | 30 |
| EAST GULF DRAINAGE | | | | | |
| Chattahoochee: Columbus, Ga | 20 | | | 21.5 | 5-6 |
| Alabama: | | | | | |
| Montgomery, Ala | 35 | 6 | 8 | 39.4 | 7 |
| Selma, Ala | 35 | 6 | 11 | 45.4 | 8 |
| Tallapoosa: Milstead, Ala | 40 | 5 | 5 | 41.0 | 5 |
| Cahaba: Centerville, Ala | 25 | 5 | 5 | 25.0 | 5 |
| Tombigbee: Lock 4, Demopolis, Ala | 30 | 6 | 12 | 45.9 | 8 |
| | | 17 | 17 | 39.0 | 17 |
| | | 28 | (2) | 42.3 | 30 |
| Pascagoula: Merrill, Miss | 20 | 6 | 12 | 24.6 | 8 |
| Chickasawhay: | | | | | |
| Enterprise, Miss | 21 | 5 | 8 | 24.3 | 7 |
| Shubuta, Miss | 27 | 5 | 11 | 35.0 | 5 |
| Leaf: Hattiesburg, Miss | 19 | 6 | 7 | 19.8 | 6 |
| Pearl: | | | | | |
| Monticello, Miss | 18 | 15 | 19 | 23.8 | 16 |
| Columbia, Miss | 18 | 7 | 7 | 18.3 | 7 |
| | | 16 | 21 | 24.0 | 19 |
| West Pearl: Pearl River, La | 13 | 5 | 28 | 17.0 | 6 |
| MISSISSIPPI DRAINAGE | | | | | |
| Shenango: Sharon, Pa | 9 | 7 | 7 | 9.1 | 7 |
| Tuscarawas: Gnadenhutten, Ohio | 9 | 6 | 12 | 10.6 | 10 |
| Hocking: Athens, Ohio | 17 | 22 | 22 | 18.3 | 22 |
| Twelve Pole Creek: Wayne, W. Va | 25 | 29 | 30 | 28.3 | 30 |
| Scioto: Circleville, Ohio | 10 | 21 | 22 | 11.2 | 21 |

1 Continued from last month. 2 Continued at end of month.

| River and station | Flood stage | Above flood stages—dates: From— | Above flood stages—dates: To— | Crest: Stage | Crest: Date |
|---|---|---|---|---|---|
| MISSISSIPPI DRAINAGE—continued | | | | | |
| | *Feet* | | | *Feet* | |
| Green: | | | | | |
| Lock No. 6, Brownsville, Ky | 30 | 10 | 13 | 32.8 | 12 |
| Lock No. 4, Woodbury, Ky | 33 | 6 | 16 | 39.5 | 11 |
| Lock No. 2, Rumsey, Ky | 34 | 9 | 25 | 40.3 | 18 |
| Big Barren: Bowling Green, Ky | 20 | 7 | 7 | 20.2 | 7 |
| Tippecanoe: Norway, Ind | 6 | 20 | 20 | 6.1 | 20 |
| White, West Fork: | | | | | |
| Elliston, Ind | 19 | 8 | 12 | 21.2 | 11 |
| Edwardsport, Ind | 15 | 8 | 14 | 17.6 | 12-13 |
| | | 23 | 26 | 15.3 | 23, 25 |
| Cumberland: | | | | | |
| Burnside, Ky | 50 | 30 | July 1 | 54.0 | 30 |
| Celina, Tenn | 45 | | | 43.9 | July 1 |
| Carthage, Tenn | 40 | July 1 | July 4 | 54.2 | July 2 |
| Nashville, Tenn | 40 | 30 | July 7 | 42.9 | July 5 |
| Clarksville, Tenn | 46 | 30 | do | 48.0 | July 2 |
| Lock F, Eddyville, Ky | 57 | | | 56.4 | July 9 |
| New: New River, Tenn | 25 | 30 | 30 | 31.2 | 30 |
| French Broad: Dandridge, Tenn | 12 | 30 | 30 | 13.9 | 30 |
| Big Pigeon: Newport, Tenn | 6 | 29 | 30 | 11.4 | 29 |
| Clinch: Clinton, Tenn | 25 | 30 | 30 | 28.6 | 30 |
| Elk: Fayetteville, Tenn | 14 | 14 | 14 | 15.8 | 14 |
| Mississippi: | | | | | |
| Alton, Ill | 21 | 22 | 23 | 21.8 | 22 |
| Chester, Ill | 27 | 22 | 24 | 28.0 | 23 |
| Cape Girardeau, Mo | 30 | 22 | 25 | 32.9 | 23 |
| New Madrid, Mo | 34 | 17 | (2) | 35.4 | 25 |
| Memphis, Tenn | 35 | 27 | 28 | 35.0 | 27-28 |
| Helena, Ark | 44 | 28 | (2) | 44.4 | 30 |
| Arkansas City, Ark | 48 | 25 | (2) | | |
| Greenville, Miss | 42 | 28 | (2) | | |
| Vicksburg, Miss | 45 | 29 | (2) | | |
| Salt: New London, Mo | 20 | 21 | 21 | 28.0 | 21 |
| Meramec: | | | | | |
| Steelville, Mo | 12 | 10 | 10 | 17.3 | 10 |
| Pacific, Mo | 11 | 10 | 13 | 18.1 | 12 |
| | | 15 | 15 | 11.7 | 15 |
| | | 20 | 23 | 16.4 | 21 |
| | | 29 | (2) | 14.5 | 30 |
| Valley Park, Mo | 14 | 10 | 13 | 20.2 | 12 |
| | | 15 | 15 | 14.1 | 15 |
| | | 20 | 23 | 20.9 | 22 |
| | | 29 | (2) | 18.2 | 30 |
| Bourbeuse: Union, Mo | 12 | 30 | 30 | 13.1 | 30 |
| St. Francis: | | | | | |
| St. Francis, Ark | 17 | 5 | (2) | 26.7 | 26 |
| Marked Tree, Ark | 17 | 26 | (2) | | |
| Missouri: | | | | | |
| Hermann, Mo | 21 | 21 | 22 | 23.7 | 21 |
| St. Charles, Mo | 25 | 13 | 14 | 25.2 | 14 |
| | | 21 | 24 | 30.1 | 21 |
| | | 29 | 29 | 25.5 | 29 |
| Solomon: Beloit, Kans | 18 | 19 | 21 | 21.0 | 20 |
| | | 24 | 26 | 22.6 | 26 |
| Grand: | | | | | |
| Gallatin, Mo | 20 | 18 | 20 | 29.6 | 19 |
| Chillicothe, Mo | 18 | 18 | 21 | 27.8 | 20 |
| Brunswick, Mo | 12 | 20 | 23 | 12.6 | 20, 22 |
| Grand, Thompsons Fork: Trenton, Mo | 20 | 18 | 18 | 22.1 | 18 |
| Osage: | | | | | |
| Quenemo, Kans | 30 | 1 | 2 | 32.6 | 2 |
| Osceola, Mo | 20 | 11 | 12 | 23.3 | 11 |
| Warsaw, Mo | 22 | 11 | 12 | 23.4 | 11 |
| Arkansas: | | | | | |
| Great Bend, Kans | 5 | 6 | 6 | 5.7 | 6 |
| | | 14 | 14 | 5.3 | 14 |
| Hutchinson, Kans | 6 | 6 | 7 | 6.2 | 6 |
| | | 8 | 8 | 6.0 | 8 |
| Arkansas City, Kans | 15 | 10 | 10 | 15.0 | 10 |
| | | 17 | 20 | 16.4 | 18 |
| Webbers Falls, Okla | 23 | 22 | 25 | 25.0 | 23 |
| Fort Smith, Ark | 22 | 14 | 15 | 22.8 | 15 |
| | | 23 | 26 | 24.8 | 24 |
| Dardanelle, Ark | 20 | 14 | 16 | 22.2 | 14 |
| | | 23 | 27 | 22.9 | 25 |
| Morrilton, Ark | 20 | 14 | 16 | 21.5 | 15 |
| | | 24 | 28 | 22.4 | 25 |
| Yancopin, Ark | 29 | 15 | (2) | | |
| Purgatoire: Higbee, Colo | 4 | 1 | 1 | 4.0 | 1 |
| Neosho: | | | | | |
| Neosho Rapids, Kans | 22 | 2 | 2 | 23.4 | 2 |
| Le Roy, Kans | 24 | 2 | 4 | 25.1 | 2 |
| | | 17 | 17 | 24.0 | 17 |
| Iola, Kans | 15 | 2 | 5 | 17.1 | 4 |
| | | 18 | 19 | 16.5 | 18 |
| Chanute, Kans | 20 | 4 | 6 | 22.0 | 5 |
| | | 9 | 9 | 20.5 | 9 |
| | | 18 | 20 | 22.9 | 19 |
| Parsons, Kans | 22 | 3 | 5 | 22.3 | 3 |
| | | 18 | 22 | 23.8 | 19, 20 |
| Oswego, Kans | 17 | 2 | 8 | 21.1 | 3 |
| | | 10 | 12 | 20.7 | 11 |
| | | 18 | 23 | 23.1 | 19, 20 |
| Wyandotte, Okla | 23 | 21 | 23 | 25.5 | 22 |
| Pensacola, Okla | 24 | 22 | 23 | 25.2 | 22 |
| Fort Gibson, Okla | 22 | 20 | 25 | 27.0 | 23 |
| Verdigris: | | | | | |
| Independence, Kans | 30 | 10 | 11 | 34.6 | 10 |
| | | 18 | 21 | 36.9 | 21 |
| Sageeyah, Okla | 35 | 23 | 25 | 37.0 | 42 |

[2] Continued at end of month.

| River and station | Flood stage | Above flood stages—dates: From— | Above flood stages—dates: To— | Crest: Stage | Crest: Date |
|---|---|---|---|---|---|
| MISSISSIPPI DRAINAGE—continued | | | | | |
| | *Feet* | | | *Feet* | |
| Canadian: | | | | | |
| Logan, N. Mex | 4 | 3 | 3 | 5.0 | 3 |
| | | 10 | 10 | 6.6 | 10 |
| Woodward, Okla | 4 | 16 | 16 | 4.0 | 16 |
| Petit Jean: Danville, Ark | 20 | 15 | 17 | 23.7 | 15 |
| | | 24 | 25 | 20.8 | 25 |
| White: | | | | | |
| Cotter, Ark | 21 | 13 | 13 | 27.8 | 13 |
| | | 22 | 24 | 34.6 | 23 |
| Calico Rock, Ark | 18 | 13 | 18 | 30.2 | 14 |
| | | 22 | 25 | 29.5 | 24 |
| Batesville, Ark | 23 | 11 | 11 | 23.7 | 11 |
| | | 13 | 19 | 37.6 | 14 |
| | | 21 | 27 | 33.0 | 24 |
| Newport, Ark | 26 | 14 | (2) | 32.6 | 25 |
| Georgetown, Ark | 22 | 15 | (2) | 29.9 | 27 |
| DeValls Bluff, Ark | 24 | 17 | (2) | 28.5 | 28-29 |
| Clarendon, Ark | 30 | 21 | (2) | | |
| Black: | | | | | |
| Leeper, Mo | 11 | 10 | 10 | 15.4 | 10 |
| | | 21 | 21 | 12.9 | 21 |
| Williamsville, Mo | 11 | 10 | 10 | 14.4 | 10 |
| | | 13 | 14 | 14.1 | 14 |
| | | 21 | 21 | 13.6 | 21 |
| | | 23 | 23 | 11.4 | 23 |
| Poplar Bluff, Mo | 14 | 10 | 16 | 17.8 | 15 |
| | | 19 | 25 | 17.7 | 23 |
| | | 30 | 30 | 14.3 | 30 |
| Corning, Ark | 11 | 5 | (2) | 15.0 | 19 |
| Black Rock, Ark | 14 | 5 | (2) | 26.6 | 22 |
| Cache: Patterson, Ark | 9 | 10 | (2) | 11.8 | 27-28 |
| Sulphur: | | | | | |
| Ringo Crossing, Tex | 20 | 24 | 27 | 25.6 | 25 |
| Finley, Tex | 24 | 28 | (2) | 28.6 | 29 |
| Cypress: Jefferson, Tex | 18 | 30 | (2) | 19.3 | July 1 |
| WEST GULF DRAINAGE | | | | | |
| Trinity: Dallas, Tex | 25 | 11 | 11 | 25.3 | 11 |
| | | 28 | 30 | 31.0 | 29 |
| Rio Grande: San Marcial, N. Mex | 3 | (1) | 7 | 3.5 | 3 |
| PACIFIC DRAINAGE | | | | | |
| Colorado: | | | | | |
| Grand Junction, Colo | 11 | (1) | 3 | 11.7 | 1 |
| Fruita, Colo | 12 | May 27 | 4 | 14.0 | 1 |
| Parker, Ariz | 7 | (1) | (2) | 11.9 | 8 |
| Colorado, Roaring Fork: Carbondale, Colo | 5 | (1) | 3 | 6.2 | 1 |
| | | 27 | 29 | 5.3 | 27 |
| Eagle: Eagle, Colo | 5 | (1) | 2 | 6.0 | May 31 |
| Gunnison: | | | | | |
| Sapinero, Colo | 19 | (1) | 3 | 20.2 | 1 |
| Delta, Colo | 9 | (1) | 10 | 11.5 | May 31 |
| Green: Elgin, Utah | 12 | (1) | 5 | 13.0 | May 31-June 1 |
| Columbia: | | | | | |
| Marcus, Wash | 24 | (1) | (2) | 34.2 | May 30-31 |
| The Dalles, Oreg | 40 | (1) | 2 | 42.1 | May 29 |
| Vancouver, Wash | 15 | (1) | 23 | 25.4 | May 31 |
| Kootenai: Bonners Ferry, Idaho | 26 | (1) | 1 | 30.0 | May 28 |
| Pend O'Reille: Newport, Wash | 16 | (1) | 18 | 24.2 | 1 |
| Willamette: Portland, Oreg | 15 | (1) | 21 | 24.4 | May 31 |

[1] Continued from last month. [2] Continued at end of month.

## MEAN LAKE LEVELS DURING JUNE, 1928

By UNITED STATES LAKE SURVEY

[Detroit, Mich., July 5, 1928]

The following data are reported in the "Notice to Mariners" of the above date:

| Data | Lakes[1]: Superior | Lakes[1]: Michigan and Huron | Lakes[1]: Erie | Lakes[1]: Ontario |
|---|---|---|---|---|
| Mean level during June, 1928: | *Feet* | *Feet* | *Feet* | *Feet* |
| Above mean sea level at New York | 602.47 | 580.12 | 572.39 | 246.59 |
| Above or below— | | | | |
| Mean stage of May, 1928 | +0.31 | +0.19 | +0.32 | −0.02 |
| Mean stage of June, 1927 | +0.21 | +0.68 | +0.19 | +0.48 |
| Average stage for June last 10 years | +0.62 | +0.02 | +0.03 | +0.40 |
| Highest recorded June stage | −0.96 | −3.49 | −2.13 | −2.04 |
| Lowest recorded June stage | +1.97 | +1.71 | +1.21 | +1.70 |
| Average departure (since 1860) of the June level from the May level | +0.28 | +0.23 | +0.17 | +0.14 |

[1] Lake St. Clair's level: In June, 1928, 575.16 feet.

## EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, JUNE, 1928

By J. B. KINCER

*General summary.*—During the first decade of June there was a continuation of wet, cloudy weather over the eastern two-thirds of the country and the temperatures remained rather unseasonably low. Cultivation was impracticable in much of the Atlantic coast section, with many row crops getting weedy; the South had more favorable weather, although cultivation was still retarded. There were generous, timely rains over the Northwest, especially in the northern Great Plains, where severe drought had prevailed and, at the close of this period, the soil was generally well supplied with moisture east of the Rocky Mountains. In the central Rockies unusually favorable conditions continued, but west of the mountains rainfall was deficient, although temperatures were mostly favorable.

During the second decade there were further beneficial rains in central-northern States, with most crops showing marked improvement. The moderate temperatures, with light rains in many parts, in the Middle and South Atlantic States were beneficial and crops made satisfactory progress quite generally in those sections, but over a large area of the central valleys frequent showers and wet soil hindered field work and many complaints were received of grassy fields and needed cultivation of row crops. Satisfactory progress was made in the central Rocky Mountain area, but to the westward dry weather continued rather generally with some deterioration of staple crops.

During the last decade continued rains in the interior valleys and Northeast were unfavorable for cultivation and warm, sunny weather was needed generally throughout the central and northern portions of the country. The comparatively high temperatures and considerable fair weather were favorable in the Atlantic coast section from Virginia southward. Considerable hail damage was reported from sections of the interior, but small grains were favored in central-northern States. West of the Rocky Mountains rain was still needed, but conditions were mostly favorable for irrigated crops.

*Small grains.*—Winter wheat made rather slow advance during the first decade due to cool weather, but conditions were mostly favorable in the West with the crop ripening as far north as Oklahoma, while in the drier sections of the Ohio Valley there were complaints of plants heading short. During the second decade the harvest of winter wheat was begun as far north as Kansas and the crop was ripe in Oklahoma, while in the northern part of the belt conditions were generally satisfactory. Harvest advanced during the last decade north to central Maryland in the East and generally over the eastern third of Kansas, but progress was slow due to the rainy weather. In the northern parts of the belt continued cool weather and ample moisture were favorable for filling.

Spring wheat deteriorated during the first decade due to the unusually dry weather over most of the belt, but at the close of the period there were beneficial rains. It continued too dry in the Pacific Northwest, with some deterioration noted. During the second decade there was marked improvement, due to the rains of the previous period, but in some sections of South Dakota the rains came late, with thin stands and plants heading short. The weather was unusually favorable during the last decade, although in the southern and eastern portions of the belt the crop was reported as headed on short straw and stands thin in many places. Persistent dryness in the far Northwest caused further deterioration in some places.

*Corn.*—In the principal producing areas corn grew rather slowly during the first decade, with cultivation backward in the Ohio Valley, although the crop was generally clean in most western parts of the belt. Good growth was reported in the Great Plains area, but in the South fair weather was needed for cultivation. During the second decade continued cool weather caused corn to make poor to only fair progress, with many complaints of weediness in the eastern part of the belt. Cultivation was well along in western sections, but in the South fields continued mostly very grassy. Some improvement was noted in the East and rains were beneficial in the Lake region. Warmth and dryness were rather badly needed in the Ohio Valley during the last decade, with some yellowing reported. Condition and progress in Iowa were very good to excellent and in the Great Plains fair to excellent advance was made, but in the South the crop was still weedy, with some still being planted on lowlands. Corn was backward in most northern sections from the Great Lakes westward, with warmth and sunshine badly needed.

*Cotton.*—During the first decade warm, sunny weather was needed in the Carolinas for best development of the cotton crop, while in Georgia it was too cloudy and wet the first part, although some improvement occurred toward the close. In the central part of the belt progress was poor to only fair, while in Arkansas conditions were favorable, except for some detrimental rains. In Louisiana progress was only fair, but in Oklahoma growth was fair to good and, while the crop was late, stands averaged good and chopping was well advanced. In Texas growth was good, with warmth and showers helpful, and squares were forming freely to the extreme northeastern part of the State.

During the second decade temperatures were generally seasonable, but there was too much rain in many sections, especially in the northern portions of the east Gulf States. In the Atlantic coast area rains were light to moderate, with progress fair to good, while in the central part of the belt rainfall interfered with cultivation and advance was mostly poor to only fair. Conditions were rather favorable in Arkansas, but in Oklahoma there was too much rain and progress of cotton was generally rather poor, although chopping was nearly finished. In Texas the weather was more favorable and growth was good to very good, with squares forming rapidly in the northeast and plants blooming freely in central and southern portions.

During the last decade the warmth in the Carolinas promoted good growth, while in Georgia, Alabama, and Mississippi generally fair weather the first part favored the crop. In Tennessee it was too cool and rainy, but in Arkansas growth was mostly very good, and in Oklahoma fair to good, except that much of the crop was weedy. The temperature averaged above normal in Texas and rainfall was of a local character, but high winds were detrimental; plants were small and uneven, but cultivation was mostly good.

*Miscellaneous crops.*—Pastures made mostly fair to excellent advance in most sections of the East during the month and the widespread and timely rains in northern parts during the first part were of great benefit; the range was generally favored in the Rocky Mountain areas, although cool weather was detrimental for a little while. Rainfall was needed rather generally west of the Mountains with complaints of dryness and some browning in

the Southwest. There was some delay to haying, particularly in central-northern parts, but in more western sections there was practically no interruption. Livestock continued in generally good condition in all sections.

Potatoes made mostly good advance throughout the month, except for some complaints of wet soil in the Ohio Valley and Lake region. Truck crops made good progress generally, although there was some slow growth due to cool weather in northern parts. Rains interfered with tobacco transplanting in central parts, but in other sections there was satisfactory progress. Sugar cane and sugar beets made good advance, although it was too cool for best growth of beets in Wyoming at the close. Citrus and deciduous fruits were generally satisfactory during the month.

# WEATHER ON THE ATLANTIC AND PACIFIC OCEANS

## NORTH ATLANTIC OCEAN

By F. A. YOUNG

June, next to July, is normally the quietest month of the year over the North Atlantic, and, taking the ocean as a whole, the current month was no exception to the general rule. The weather conditions differed greatly, however, in different localities, as over the middle and eastern sections of the steamer lanes gales were reported on from 1 to 3 days, while at the time of writing no reports have been received showing a wind force of 8 or over west of the fifty-fifth meridian, with the exception of a disturbance on the 30th between Hatteras and New York.

The North Atlantic HIGH and Icelandic LOW were both comparatively inactive during the greater part of the month, and at times unusually low pressure in the vicinity of the Azores was responsible for unfavorable weather in that region.

Charts VIII to XI show the conditions from the 15th to 18th, inclusive, during the flight of the airplane *Friendship* with Stultz, pilot, Gordon, mechanic, and Miss Earhart on board, and also the two days previous to the flight, which began on the 17th and ended on the 18th.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian), North Atlantic Ocean, June, 1928*

| Stations | Average pressure | Departure [1] | Highest | Date | Lowest | Date |
|---|---|---|---|---|---|---|
| | *Inches* | *Inch* | *Inches* | | *Inches* | |
| Julianehaab, Greenland | 30.01 | ([2]) | 30.28 | 14th | 29.76 | 27th. |
| Belle Isle, Newfoundland | 29.83 | −0.01 | 30.12 | 21st | 29.34 | 11th. |
| Halifax, Nova Scotia | 29.94 | +0.01 | 30.20 | 29th | 29.58 | 1st. |
| Nantucket | 29.92 | −0.07 | 30.14 | 11th [3] | 29.64 | 2d. |
| Hatteras | 29.97 | −0.04 | 30.12 | 12th [3] | 29.78 | 7th. |
| Key West | 29.99 | −0.01 | 30.06 | 14th | 29.88 | 16th. |
| New Orleans | 29.96 | +0.01 | 30.08 | 15th | 29.76 | 3d. [3] |
| Cape Gracias, Honduras | 29.86 | −0.01 | 29.90 | 30th | 29.82 | 3d. [3] |
| Turks Island | 30.05 | −0.04 | 30.12 | 2d [3] | 29.98 | 30th. |
| Bermuda | 30.15 | +0.05 | 30.32 | 4th | 29.98 | 17th. |
| Horta, Azores | 30.05 | −0.16 | 30.36 | 14th | 29.60 | 7th. |
| Lerwick, Shetland Islands | 29.75 | −0.05 | 30.35 | 1st | 29.21 | 10th. |
| Valencia, Ireland | 29.88 | −0.12 | 30.36 | 15th | 28.88 | 9th. |
| London | 29.94 | +0.01 | 30.29 | 2d | 29.40 | 9th. |

[1] From normals shown on Hydrographic Office Pilot Chart, based on observations at Greenwich mean noon, or 7 a. m. seventy-fifth meridian.
[2] No normal available.
[3] And on other date or dates.

Fog was unusually prevalent over the Grand Banks and along the American coast north of the thirty-fifth parallel, being reported on from 19 to 23 days in these localities. Fog was also observed on from 3 to 6 days over the middle and eastern section of the steamer lanes and on 1 day off the west coast of Florida.

On the 2d a moderate depression was central near 40° N., 15° W.; this moved slowly northeastward and on the 10th and 11th was over the North Sea. On the 2d and 3d moderate gales prevailed over a limited area between the Madeiras and fortieth parallel, and on the 9th between the Irish coast and tenth meridian. On the 7th and 8th moderate gales were also reported by vessels between the Azores and fortieth meridian.

On the 11th a shallow depression was central near 47° N., 30° W.; and on the 12th and 13th moderate weather with slight pressure gradients prevailed generally. On the 14th two disturbances of no great force were over the ocean; the first central near 43° N., 45° W., and the second over the English Channel, while moderate gales occurred near the centers of both.

By the 15th, as shown on Chart VIII, the western LOW had moved but little, but the storm area on that day was by far the most extensive of the month, reaching from the thirtieth to fifty-fifth meridians and thirty-fifth to forty-fifth parallels, with a region of comparatively moderate winds between the thirty-fifth and forty-fifth meridians.

As shown on Charts X and XI, moderate weather prevailed generally on the 17th and 18th, the conditions on the 19th being similar.

On the 20th a LOW was central near 50° N., 35° W., accompanied by moderate westerly gales; this moved eastward and on the 23d was off the east coast of Scotland. On the 21st strong westerly gales were encountered near 50° N., 25° W., and on the 22d northerly winds of equal force occurred near 58° N., 19° W.

Capt. E. Richter, of the German S. S. *Concho* (ex-American), from Baltimore to Danzig, reports that on June 23, in 46° 39′ N., 29° 33′ W., he met an unusually heavy storm from the east by south. It began at noon, with continuous heavy rain. The wind held in the same direction until 2 a. m. on the 24th. The rain stopped at 11 p. m. on the 23d and the wind suddenly shifted to south-southwest, force 6. At 3 a. m. a few bright stripes were seen in the northwest, when a thick fog came up. After an hour it suddenly cleared and the wind blew very hard from the northwest. The lowest barometer, 29.38 inches (uncorrected), occurred at 2 a. m. on the 24th.

On the 24th and 25th a disturbance was again over the eastern section of the steamer lanes, the storm area extending from the fifteenth to thirtieth meridians on the former date, and from the Irish coast to the twentieth meridian on the latter. On the 26th a number of land stations on the coast of Great Britain reported northerly to westerly winds of force 7 and 8.

From the 27th until the end of the month moderate conditions were the rule, although on the 27th and 28th a few vessels in the eastern section of the steamer lanes reported moderate southerly gales, and on the 30th the only disturbance of the month in American waters occurred off the coast between Hatteras and New York, as shown by storm report in table from Am. S. S. *Gulfking*.

## OCEAN GALES AND STORMS, JUNE, 1928

| Vessel | Voyage | | Position at time of lowest barometer | | Gale began | Time of lowest barometer | Gale ended | Lowest barometer | Direction of wind when gale began | Direction and force of wind at time of lowest barometer | Direction of wind when gale ended | Highest force of wind and direction | Shifts of wind near time of lowest barometer |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | From— | To— | Latitude | Longitude | | | | | | | | | |
| **NORTH ATLANTIC OCEAN** | | | ° ′ | ° ′ | | | | Inches | | | | | |
| Saucon, Am. S. S. | Valencia, Spain. | New York | 40 20 N. | 18 31 W. | June 2 | 8p, 3 | June 4 | 29.31 | SSW | WNW., 7 | WNW. | SW., 9 | SSW. WNW. |
| Steel Worker, Am. S. S. | New York | Port Said | 38 46 N. | 24 49 W. | 7 | 7p, 7 | 8 | 29.34 | S | SSW., 9 | WSW | —, 9 | SSW. WSW. |
| Sylvafield, Br. M. S. | Canal Zone | Hamburg | 48 26 N. | 16 14 W. | 8 | 3p, 8 | 9 | 28.74 | ENE | NE., 9 | N | N., 9 | NE. NNW. |
| Abercos, Am. S. S. | London | Galveston | 49 20 N. | 8 32 W. | 8 | 11a, 9 | 10 | 29.09 | S | S., 10 | SW | S., 10 | Steady. |
| Hamburg, Ger. S. S. | Channel | New York | 43 47 N. | 42 25 W. | 14 | 8a, 14 | 15 | 29.45 | SE | SSE., 8 | NW | SSE., 10 | SE. SSW. |
| Nieuw Amsterdam, Du. S. S. | Rotterdam | do | 41 41 N. | 46 18 W. | 15 | 3a, 15 | 15 | 29.40 | WNW | NW., 7 | NW | WNW., 9. | |
| Arminco, Belg. S. S | Port Arthur. | Mediterranean. | 37 50 N. | 30 09 W. | 15 | 11p, 15 | 16 | 29.84 | S | SSW., 8 | WSW | S., 9 | S. WSW. |
| Mercer, Am. S. S. | Rotterdam | New York | 47 15 N. | 31 00 W. | 20 | 9p, 20 | 21 | 29.66 | WSW | —, 9 | W | WNW., 10 | WSW. W. |
| Gonzenheim, Ger. S. S. | Emden | Portland, Me. | 50 00 N. | 22 10 W. | 20 | 4p, 20 | 22 | 29.25 | S | S., 7 | SW | W., 10 | |
| Rathlin Head, Br. S. S. | Bremen | Montreal | 58 44 N. | 19 30 W. | 22 | —, 22 | 22 | 29.29 | WNW | NNW., 9 | NW | —, 9 | |
| Lubrafol, Belg. S. S. | Port Arthur | Hamburg | 48 37 N. | 19 45 W. | 24 | 2p, 24 | 25 | 29.59 | SE | SE., 10 | SW | S., 10 | SE. S. W. |
| Columbus, Ger. S. S. | Plymouth | New York | 49 45 N. | 11 17 W. | 25 | 4p, 25 | 26 | 29.48 | S | W., 8 | NNW. | NW., 10 | SW. WNW. |
| Gulfking, Am. S. S. | Beverly, Mass | Port Arthur | 38 00 N. | 70 51 W. | 30 | 4a, 30 | 30 | 29.84 | SSW | SSW., 8 | SW | —, 9 | Steady. |
| **NORTH PACIFIC OCEAN** | | | | | | | | | | | | | |
| Hayo Maru, Jap. S. S. | Muroran | Vancouver | 44 29 N. | 150 34 E. | 4 | 4p, 4 | 5 | 29.54 | NNE | N., 8 | NNW | N., 9 | NNE.-N. |
| California, Am. S. S. | Portland | Aomori, Japan | 51 05 N. | 178 40 W. | 4 | 8p, 5 | 5 | 29.22 | S | SSE., 7 | SSE | SSE., 9 | Steady. |
| Nora, Am. S. S. | San Pedro | Balboa | 13 45 N. | 95 14 W. | 5 | Noon | 5 | 29.67 | NE | S., - | SW | SE., 10 | NE.-SE.-SW. |
| Eldridge, Am. S. S. | Philippines | Puget Sound | 19 30 N. | 127 18 E. | 13 | 8p, 13 | 13 | 29.50 | NW | NW., 5 | WNW. | NW., 8 | NW.-SW. |
| Calmar, Am. S. S. | San Pedro | Balboa | 17 06 N. | 100 26 W. | 16 | 9a, 16 | 17 | 29.65 | ESE | ESE., 7 | SW | SW., 8 | ESE.-SW. |
| Canadian Miller, Br. S. S | Union Bay | Panama | 19 04 N. | 105 13 W. | 17 | Noon | 17 | 29.68 | SE | SE.- | E | SE., 8 | SE.-E. |
| Crosskeys, Am. S. S. | Dairen | San Francisco | 45 25 N. | 172 15 W. | 22 | 8a, 23 | 23 | 29.03 | NE | S., 6 | S | NE., 9 | |
| Silvercedar, Br. M. S. | Philippines | do | 41 54 N. | 167 18 W. | 22 | Noon, 22 | 23 | 29.57 | ESE | SSW., 8 | SSW | SSW., 9 | Steady. |
| Pacific Commerce, Br. M. S. | Yokohama | Portland | 40 56 N. | 152 40 E. | 25 | 8a, 26 | 26 | 29.23 | ENE | NNW., 9 | NW | NNW., 9 | ENE.-NNW. |
| Akibasan Maru, Jap. S. S | do | San Francisco | 48 00 N. | 177 45 W. | 28 | Noon, 28 | 29 | 29.51 | ESE | ENE., 9 | NE | NE., 9 | |
| **SOUTH PACIFIC OCEAN** | | | | | | | | | | | | | |
| Sonoma, Am. S. S. | San Francisco | Sydney | 33 25 S. | 152 00 E. | 14 | —, 14 | | 29.24 | SSE | SSE., 11 | | | Steady. |

### NORTH PACIFIC OCEAN

By WILLIS E. HURD

The center of the Aleutian cyclone, which had been situated for several months over the northwestern waters of the Gulf of Alaska, drifted to the westward, and in June lay over the middle Aleutians, lowest average pressure 29.80 inches, at Dutch Harbor. Over most of the region usually more or less subject to the influence of this great depression, the barometric average this month was practically normal, except at Dutch Harbor, where it was a fifth of an inch below.

The North Pacific anticyclone was stable and highly developed throughout the month, central near 40° N., 145° W.

Pressure data for several island and American coast stations in west longitudes are given in the following table:

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean, June, 1928*

| Stations | Average pressure | Departure from normal | Highest | Date | Lowest | Date |
|---|---|---|---|---|---|---|
| | *Inches* | *Inch* | *Inches* | | *Inches* | |
| Dutch Harbor [1] | 29.80 | −0.19 | 30.28 | 26th | 29.06 | 24th. |
| St. Paul [1] [3] | 29.86 | −0.03 | 30.36 | 28th | 29.24 | 24th. |
| Kodiak [1] | 29.91 | −0.03 | 30.36 | 6th [6] | 29.54 | 24th. |
| Midway Island [1] [2] | 30.03 | −0.04 | 30.28 | 2d | 29.72 | 7th. |
| Honolulu [4] | 30.01 | −0.03 | 30.09 | 9th | 29.87 | 6th. |
| Juneau [4] | 30.03 | +0.02 | 30.27 | 7th | 29.73 | 11th. |
| Tatoosh Island [4] [5] | 30.02 | −0.03 | 30.23 | 5th | 29.76 | 20th. |
| San Francisco [4] [5] | 29.90 | −0.06 | 30.03 | 14th | 29.64 | 18th. |
| San Diego [4] [5] | 29.87 | −0.02 | 29.96 | 12th | 29.73 | 17th. |

[1] P. m. observations only.
[2] For 29 days.
[3] For 27 days.
[4] A. m. and p. m. observations.
[5] Corrected to 24-hour mean.
[6] And on other date.

Although fewer gales, exceeding force 8, occurred in June than in May, yet the number of days with gales increased, especially over the middle portion of the upper steamship routes, owing to the unusual energy, for the season, of the cyclone over the central Aleutians. Most of the gales, however, were of a very moderate character, only a small number exceeding 8 in force, and none of them exceeding force 10. Moderate gales occurred along the California and Oregon coasts on the 12th, 17th, and 18th, due to intensification of the gradients existing there between the oceanic anticyclone and the low-pressure region over the continent.

Several depressions, or cyclones, of no great energy, some tropical and others of continental origin, appeared over the waters of the Far East. A few were accompanied by local gales of force 8 or 9 between Japan and longitude 160° E., and one caused a moderate northwesterly gale northeast of Luzon on the 13th. Otherwise so far as known none was productive of high winds.

The severest gale reported for the entire ocean occurred south of the Gulf of Tehuantepec on the 5th. Mr. B. Vieda, second officer and observer of the American steamer *Nora*, which encountered this wind, said of it that at 11 a. m. it "reached force 10 and kept hauling from northeast to east to southeast to south at the same force until 1:30 p. m. Heavy rain and large rough sea during the blow." The barometer at the time read 29.67 inches, which showed a depression of about two-tenths of an inch from earlier and following readings, showing that a cyclonic disturbance was at hand. Other gales, but of a more moderate character, produced by active depressions off the Mexican coast, occurred between Salina Cruz and Manzanillo on the 17th, 18th, and 25th.

Concerning the weather off this coast, Mr. J. L. Kilburn, second officer and observer of the British freighter *General Smuts*, makes the following comment:

> From the 13th to 18th June a heavy confused swell running from a southwest to northwest direction was encountered, wind SW./WSW., force 4–6, barometer 29.70–29.80; overcast, with frequent squalls of torrential rain. This is the first time we have encountered this weather on this track—a comparatively moderate wind, steady in direction, accompanied by such a short, heavy, confused swell of such long duration and covering so big an area (3½° N.–16½° N. lat., 89° W.–103° W. lon.).

The northeast trades were steady throughout the month. At Honolulu the prevailing direction was from the east, the maximum velocity being at the rate of 22 miles an hour, from the east, on the 18th.

Fog was frequent and had increased slightly in the number of days of occurrence since May over the west-

ern half of the upper steamship routes. Over the eastern half the increase was vastly greater, the percentage over some portions of the area between 45° and 55° N., 150° and 60° W., rising to 40 or higher where there was little or no fog reported on the preceding month. Scattered fog occurred along all the American coast north of the twentieth parallel and was as frequent off Cape San Lucas as at any point above it. In Bering Sea fog was reported at St. Paul Island on 13 days.

---

*Storm at Valparaiso, Chile.*—According to the New York Maritime Register of June 6, 1928, one of the severest storms of years at Valparaiso occurred there a few days previously. The Grace Line's new motorship *Santa Maria* arrived there on May 31 during a storm of such violence that she was unable to begin discharging cargo. The gale did not abate until June 2. Seven small craft were reported wrecked in the harbor, and a quantity of merchandise lost, during the three days' storm.—*W. E. Hurd.*

*Southwest monsoon—Sand haze.*—Several vessels in the western part of the Arabian Sea experienced an unusually strong southwest monsoon during June. The heaviest winds, which at times attained the force of a whole gale, were reported on the 13th and 14th between 10° and 15° north latitude, 55° and 60° east longitude.

On several days of the month very thick weather due to sand haze overhung the lower part of the Red Sea and the Gulf of Aden.—*W. E. Hurd.*

# CLIMATOLOGICAL TABLES[1]

## CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

*Condensed climatological summary of temperature and precipitation by sections, June, 1928*

| Section | Temperature | | | | | | | | Precipitation | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Section average | Departure from the normal | Monthly extremes | | | | | | Section average | Departure from the normal | Greatest monthly | | Least monthly | |
| | | | Station | Highest | Date | Station | Lowest | Date | | | Station | Amount | Station | Amount |
| | °F. | °F. | | °F. | | | °F. | | In. | In. | | In. | | In. |
| Alabama | 76.0 | −2.3 | Eufaula | 99 | 20 | Valley Head | 50 | 7 | 10.16 | +5.90 | Citronelle | 17.89 | Alaga | 3.14 |
| Arizona | 75.9 | −0.2 | 2 stations | 117 | [2] 6 | Spring Valley ranger station. | 21 | 13 | 0.03 | −0.36 | Cedar Glade | 1.07 | 80 stations | 0.00 |
| Arkansas | 73.5 | −3.6 | Amity | 100 | [2] 19 | Dutton | 40 | 6 | 9.44 | +5.42 | Pocahontas | 17.16 | Amity | 4.01 |
| California | 67.8 | +0.4 | Greenland Ranch | 120 | 7 | Helm Creek | 20 | 29 | 0.00 | −0.22 | Steele Swamp | 1.67 | 135 stations | 0.00 |
| Colorado | 57.6 | −3.6 | 2 stations | 100 | [2] 16 | Pearl | 17 | 13 | 2.15 | +0.62 | Peetz | 8.84 | Ignacio | 0.00 |
| Florida | 79.4 | −0.5 | Mount Pleasant | 101 | 20 | Hilliard | 53 | 8 | 6.76 | +0.17 | St. Leo | 12.61 | Crescent City | 2.23 |
| Georgia | 76.8 | −1.2 | Eastman | 105 | 20 | Blue Ridge | 43 | 8 | 5.93 | +1.52 | Clayton | 10.56 | Dublin | 2.82 |
| Idaho | 57.8 | −2.4 | Orofino | 103 | 25 | Smith Ferry | 21 | 5 | 1.15 | −0.20 | Big Springs | 3.41 | Bogus Creek | T. |
| Illinois | 66.9 | −5.0 | Jacksonville | 93 | 12 | Mount Carroll | 35 | 10 | 7.25 | +3.38 | Anna | 18.21 | Pontiac | 3.33 |
| Indiana | 65.8 | −5.8 | Collegeville | 92 | 30 | 2 stations | 35 | 3 | 7.05 | +3.22 | Evans Landing | 13.18 | Huntington | 2.79 |
| Iowa | 64.5 | −4.8 | 4 stations | 88 | 20 | Mason City | 31 | 2 | 5.38 | +0.80 | Keosauqua | 10.31 | Cherokee | 2.31 |
| Kansas | 67.3 | −6.0 | Richfield | 97 | 7 | Healy | 37 | 5 | 7.35 | +3.47 | Oswego | 16.40 | Elkhart | 2.03 |
| Kentucky | 69.5 | −4.4 | Williamsburg | 93 | [2] 19 | 2 stations | 45 | 8 | 10.88 | +6.79 | Paducah | 19.22 | Sergent | 3.50 |
| Louisiana | 78.9 | −1.2 | 2 stations | 97 | [2] 1 | 4 stations | 53 | 6 | 9.85 | +5.04 | Franklin | 19.06 | Shreveport | 3.30 |
| Maryland-Delaware | 69.1 | −1.8 | Coleman, Md | 94 | 14 | Oakland, Md | 34 | 1 | 5.78 | +1.85 | Chewsville, Md | 11.57 | Takoma, Md | 2.45 |
| Michigan | 59.6 | −4.4 | Houghton Lake | 89 | 22 | Wolverine | 20 | 3 | 4.53 | +1.47 | Yale | 10.50 | Whitefish Point | 1.32 |
| Minnesota | 60.1 | −4.1 | Beardsley | 93 | 26 | Meadowlands | 22 | 3 | 3.99 | −0.27 | Tower | 7.35 | Montevideo | 1.44 |
| Mississippi | 77.4 | −1.4 | Aberdeen | 100 | 20 | Lake | 52 | 6 | 9.34 | +5.11 | Fruitland Park | 20.76 | Holly Bluff | 2.50 |
| Missouri | 67.7 | −5.8 | Nevada | 91 | 21 | Mountain Grove | 40 | 6 | 11.17 | +6.50 | Jackson | 22.00 | Hannibal | 5.08 |
| Montana | 56.1 | −3.4 | Heron | 94 | 25 | Conway's ranch | 21 | 9 | 3.27 | +0.67 | Adel | 11.37 | Columbia Falls | 1.06 |
| Nebraska | 63.0 | −6.3 | 2 stations | 96 | 30 | Gordon | 27 | 10 | 4.63 | +0.83 | Sidney | 7.74 | Wakefield | 1.71 |
| Nevada | 64.7 | −0.7 | Logandale | 112 | 6 | 2 stations | 21 | 18 | 0.43 | −0.07 | Hylton | 2.14 | 8 stations | 0.00 |
| New England | 61.4 | −2.2 | North Grosvenor Dale, Conn. | 91 | 15 | Pittsburg "A," N. H. | 28 | 15 | 4.79 | +1.46 | Chesterfield, Mass | 9.22 | Berlin, N. H | 2.07 |
| New Jersey | 66.6 | −1.7 | 2 stations | 93 | 14 | Charlotteburg | 36 | 11 | 6.75 | +2.96 | Culvers Lake | 10.34 | Atlantic City | 3.03 |
| New Mexico | 68.7 | −0.1 | Carlsbad | 110 | 27 | Luna ranger station | 25 | [2] 12 | 0.57 | −0.82 | Quay | 5.16 | 41 stations | 0.00 |
| New York | 62.4 | −2.5 | Dansville | 92 | 13 | 2 stations | 28 | [2] 16 | 6.13 | +2.45 | Jamestown | 11.00 | Gabriels | 1.83 |
| North Carolina | 73.0 | −0.5 | Goldsboro | 106 | 20 | Mount Mitchell | 33 | 7 | 5.49 | +0.76 | Rock House | 10.53 | Hatteras | 1.46 |
| North Dakota | 58.2 | −4.6 | Melville | 92 | 30 | Melville | 24 | 8 | 5.07 | +1.57 | Stowers | 10.61 | Power | 1.88 |
| Ohio | 65.0 | −4.6 | 2 stations | 92 | [2] 12 | Garfield | 32 | 3 | 6.79 | +3.04 | Pleasant Hill | 9.93 | Danbury | 3.81 |
| Oklahoma | 74.3 | −2.9 | 3 stations | 107 | [2] 18 | 2 stations | 40 | 4 | 6.26 | +2.35 | Wyandotte | 15.43 | Fort Reno | 1.30 |
| Oregon | 59.9 | −0.5 | 4 stations | 105 | 24 | Fremont | 19 | 8 | 0.91 | −0.35 | Welches | 4.46 | Hermiston | T. |
| Pennsylvania | 65.5 | −2.7 | Phoenixville | 93 | 14 | Wellsboro | 30 | 12 | 7.96 | +3.86 | West Chester | 13.14 | Erie | 3.96 |
| South Carolina | 76.0 | −1.5 | 2 stations | 102 | 21 | 3 stations | 47 | 8 | 5.58 | +0.75 | Camden | 13.94 | Marion | 2.71 |
| South Dakota | 61.3 | −4.7 | Vivian | 95 | 5 | Pollock | 28 | 10 | 4.05 | +0.42 | Timber Lake | 7.58 | Pierre | 2.18 |
| Tennessee | 71.8 | −2.7 | Etowah | 96 | [2] 19 | Sewanee | 39 | 7 | 10.18 | +5.81 | Dresden | 18.67 | Memphis | 3.96 |
| Texas | 80.1 | 0.0 | Spur | 113 | 28 | Romero | 40 | 4 | 3.91 | +0.64 | Winfield (near) | 14.52 | 4 stations | 0.00 |
| Utah | 62.4 | −2.1 | 2 stations | 108 | [2] 20 | Park City | 20 | 18 | 0.63 | +0.02 | Ibapah | 2.84 | 9 stations | 0.00 |
| Virginia | 70.2 | −1.6 | 2 stations | 98 | [2] 20 | Burkes Garden | 36 | [2] 1 | 5.00 | +0.95 | Lincoln | 8.11 | Roanoke | 2.22 |
| Washington | 60.7 | 0.0 | 3 stations | 105 | [2] 24 | Bumping Lake | 26 | 7 | 1.10 | −0.41 | Tye | 4.87 | Mottinger | 0.03 |
| West Virginia | 66.7 | −2.6 | White Sulphur Springs. | 96 | 20 | Bayard | 33 | 1 | 7.37 | +2.76 | Pickens | 11.69 | Upper Tract | 1.55 |
| Wisconsin | 60.2 | −4.3 | 3 stations | 88 | [2] 22 | Solon Springs | 26 | 3 | 4.24 | +0.25 | Brodhead | 7.45 | Plum Island | 2.47 |
| Wyoming | 53.9 | −5.3 | Wheatland | 96 | 30 | Hunter's Station | 18 | 1 | 3.01 | +1.42 | Dome Lake | 6.76 | Green River | 0.15 |
| Alaska | | | | | | | | | | | | | | |
| Hawaii | | | | | | | | | | | | | | |
| Porto Rico | 78.5 | 0.2 | Arecibo | 96 | 18 | 2 stations | 59 | 14 | 2.91 | −3.60 | Maricao | 6.00 | Santa Rita | 0.35 |

[1] For description of tables and charts, see REVIEW, January, p. 29.

[2] Other dates also.

TABLE I.—*Climatological data for Weather Bureau stations, June, 1928*

| District and station | Elevation of instruments: Barometer above sea level | Thermometer above ground | Anemometer above ground | Pressure: Station reduced to mean of 24 hours | Sea level, reduced to mean of 24 hours | Departure from normal | Temperature of the air: Mean max. + mean min. ÷ 2 | Departure from normal | Maximum | Date | Mean maximum | Minimum | Date | Mean minimum | Greatest daily range | Mean wet thermometer | Mean temperature of the dew point | Mean relative humidity | Precipitation: Total | Departure from normal | Days with .01, or more | Wind: Total movement | Prevailing direction | Maximum velocity: Miles per hour | Direction | Date | Clear days | Partly cloudy days | Cloudy days | Average cloudiness, tenths | Total snowfall | Snow, sleet, and ice on ground at end of month |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ft. | Ft. | Ft. | In. | In. | In. | °F. | °F. | °F. | | °F. | °F. | | °F. | °F. | °F. | °F. | % | In. | In. | | Miles | | | | | | | | 0-10 | In. | In. |
| *New England* | | | | | | | 61.6 | -1.9 | | | | | | | | | | 81 | 4.16 | +1.2 | | | | | | | | | | 6.5 | | |
| Eastport | 76 | 67 | 85 | 29.82 | 29.89 | -0.04 | 54.6 | -0.5 | 75 | 13 | 62 | 44 | 3 | 47 | 29 | 51 | 47 | 80 | 3.52 | +0.6 | 14 | 5,680 | s. | 25 | se. | 9 | 3 | 13 | 14 | 7.3 | 0.0 | 0.0 |
| Greenville, Me. | 1,070 | 6 | ---- | 28.74 | 29.89 | ---- | 57.6 | ---- | 80 | 13 | 68 | 38 | 5 | 48 | 34 | ---- | ---- | ---- | 3.58 | ---- | 15 | ---- | se. | ---- | ---- | ---- | 4 | 14 | 12 | ---- | 0.0 | 0.0 |
| Portland, Me. | 103 | 82 | 117 | 29.80 | 29.92 | -.03 | 60.0 | -2.5 | 81 | 13 | 67 | 47 | 11 | 53 | 27 | 55 | 50 | 74 | 3.32 | 0.0 | 15 | 5,409 | s. | 24 | s. | 9 | 12 | 6 | 12 | 5.6 | 0.0 | 0.0 |
| Concord | 289 | 70 | 79 | 29.58 | 29.89 | -.07 | 61.0 | -1.9 | 86 | 14 | 71 | 39 | 17 | 51 | 37 | ---- | ---- | ---- | 4.43 | +1.2 | 12 | 3,603 | se. | 25 | n. | 14 | 9 | 9 | 12 | 6.2 | 0.0 | 0.0 |
| Burlington | 403 | 11 | 48 | 29.43 | 29.86 | -.10 | 62.2 | -3.5 | 82 | 13 | 71 | 43 | 16 | 54 | 29 | ---- | ---- | ---- | 3.14 | -0.2 | 15 | 5,586 | s. | 31 | s. | 9 | 2 | 11 | 17 | 7.4 | 0.0 | 0.0 |
| Northfield | 876 | 12 | 60 | 28.96 | 29.90 | -.06 | 58.4 | -2.9 | 83 | 13 | 69 | 37 | 17 | 48 | 39 | 56 | 54 | 83 | 2.79 | -0.4 | 13 | 4,321 | s. | 24 | w. | 2 | 0 | 17 | 13 | 7.4 | 0.0 | 0.0 |
| Boston | 125 | 115 | 188 | 29.76 | 29.90 | -.06 | 65.0 | -1.5 | 90 | 14 | 73 | 51 | 23 | 58 | 28 | 58 | 54 | 73 | 5.56 | +2.7 | 14 | 5,860 | sw. | 21 | s. | 9 | 7 | 10 | 13 | 6.3 | 0.0 | 0.0 |
| Nantucket | 12 | 14 | 90 | 29.90 | 29.91 | -.07 | 60.6 | -0.4 | 77 | 15 | 67 | 49 | 23 | 54 | 21 | 57 | 56 | 90 | 4.34 | +1.9 | 14 | 9,907 | sw. | 36 | sw. | 2 | 6 | 11 | 13 | 6.5 | 0.0 | 0.0 |
| Block Island | 26 | 11 | 46 | 29.86 | 29.89 | -.08 | 61.2 | -0.6 | 72 | 15 | 66 | 52 | 11 | 56 | 18 | 58 | 56 | 89 | 4.42 | +1.8 | 13 | 9,775 | sw. | 34 | n. | 20 | 5 | 9 | 16 | 6.6 | 0.0 | 0.0 |
| Providence | 160 | 215 | 251 | 29.73 | 29.90 | -.07 | 64.2 | -4.1 | 84 | 27 | 72 | 49 | 11 | 56 | 26 | 58 | 54 | 76 | 3.70 | +1.0 | 18 | 6,984 | nw. | 32 | nw. | 10 | 7 | 9 | 14 | 6.4 | 0.0 | 0.0 |
| Hartford | 159 | 122 | ---- | 29.74 | 29.91 | -.06 | 65.2 | -1.9 | 85 | 14 | 73 | 50 | 17 | 57 | 29 | ---- | ---- | ---- | 4.41 | +1.3 | 14 | ---- | s. | ---- | ---- | ---- | 11 | 7 | 12 | 5.7 | 0.0 | 0.0 |
| New Haven | 106 | 74 | 153 | 29.79 | 29.90 | -.07 | 65.6 | -1.0 | 84 | 27 | 73 | 49 | 11 | 58 | 24 | 60 | 58 | 80 | 6.09 | +3.0 | 13 | 5,521 | s. | 25 | ne. | 20 | 8 | 12 | 10 | 5.9 | 0.0 | 0.0 |
| *Middle Atlantic States* | | | | | | | 68.4 | -1.8 | | | | | | | | | | 76 | 6.15 | +2.5 | | | | | | | | | | 6.4 | | |
| Albany | 97 | 102 | 115 | 29.78 | 29.88 | -.09 | 65.7 | -2.3 | 85 | 25 | 74 | 46 | 11 | 57 | 29 | 60 | 57 | 78 | 8.22 | +4.8 | 15 | 4,254 | s. | 26 | s. | 9 | 10 | 8 | 12 | 5.5 | 0.0 | 0.0 |
| Binghamton | 871 | 10 | 84 | 28.96 | 29.87 | -.10 | 63.8 | -1.8 | 85 | 25 | 73 | 38 | 11 | 54 | 37 | ---- | ---- | ---- | 9.51 | +5.9 | 18 | 3,361 | e. | 18 | sw. | 6 | 6 | 9 | 15 | 6.6 | 0.0 | 0.0 |
| New York | 314 | 414 | 454 | 29.57 | 29.90 | -.08 | 66.6 | -2.2 | 85 | 25 | 74 | 53 | 6 | 60 | 27 | 60 | 57 | 75 | 6.12 | +2.8 | 17 | 9,108 | s. | 51 | nw. | 14 | 2 | 15 | 13 | 7.2 | 0.0 | 0.0 |
| Harrisburg | 374 | 94 | 104 | 29.50 | 29.90 | -.08 | 67.2 | -3.1 | 86 | 14 | 75 | 51 | 11 | 59 | 25 | 61 | 57 | 75 | 8.16 | +4.6 | 16 | 4,009 | s. | 26 | w. | 29 | 4 | 9 | 17 | 7.2 | 0.0 | 0.0 |
| Philadelphia | 114 | 123 | 341 | 29.78 | 29.91 | -.07 | 69.8 | -1.6 | 88 | 14 | 77 | 57 | 23 | 62 | 23 | 63 | 60 | 76 | 6.77 | +3.5 | 18 | 5,900 | sw. | 30 | nw. | 14 | 5 | 14 | 11 | 6.7 | 0.0 | 0.0 |
| Reading | 325 | 81 | 98 | 29.55 | 29.89 | ---- | 67.8 | ---- | 89 | 14 | 76 | 50 | 16 | 60 | 25 | 62 | 58 | 74 | 6.18 | +2.5 | 16 | 4,109 | se. | 20 | w. | 6 | 6 | 8 | 16 | 6.6 | 0.0 | 0.0 |
| Scranton | 805 | 111 | 119 | 29.05 | 29.90 | -.08 | 65.0 | -2.8 | 87 | 14 | 74 | 42 | 11 | 56 | 35 | 59 | 55 | 73 | 6.76 | +3.2 | 16 | 4,029 | s. | 24 | nw. | 14 | 4 | 10 | 16 | 5.9 | 0.0 | 0.0 |
| Atlantic City | 52 | 37 | 172 | 29.85 | 29.90 | -.08 | 66.0 | -0.6 | 84 | 2 | 72 | 56 | 16 | 61 | 25 | 62 | 59 | 83 | 3.03 | 0.0 | 14 | 10,398 | s. | 43 | s. | 29 | 6 | 16 | 8 | 5.5 | 0.0 | 0.0 |
| Cape May | 17 | 13 | 49 | ---- | ---- | ---- | 68.0 | +0.3 | 84 | 19 | 76 | 53 | 16 | 60 | 22 | ---- | ---- | ---- | 3.95 | ---- | 14 | ---- | s. | ---- | ---- | ---- | 6 | 15 | 9 | ---- | 0.0 | 0.0 |
| Sandy Hook | 22 | 10 | 55 | 29.87 | 29.89 | ---- | 66.6 | ---- | 82 | 25 | 72 | 56 | 23 | 61 | 22 | 61 | 58 | 80 | 6.37 | ---- | 16 | 8,180 | s. | 46 | nw. | 14 | 6 | 12 | 12 | 6.3 | 0.0 | 0.0 |
| Trenton | 190 | 159 | 183 | 29.69 | 29.89 | ---- | 67.8 | ---- | 90 | 14 | 76 | 52 | 11 | 59 | 27 | 61 | 57 | 74 | 5.90 | +2.4 | 15 | 6,012 | sw. | 31 | nw. | 14 | 4 | 9 | 17 | 7.1 | 0.0 | 0.0 |
| Baltimore | 123 | 100 | 215 | 29.76 | 29.89 | -.10 | 71.0 | -1.7 | 93 | 14 | 78 | 57 | 16 | 64 | 23 | 64 | 60 | 71 | 4.43 | +0.6 | 17 | 6,570 | sw. | 28 | sw. | 9 | 4 | 14 | 12 | 6.7 | 0.0 | 0.0 |
| Washington | 112 | 62 | 85 | 29.77 | 29.89 | -.11 | 71.0 | -1.2 | 91 | 14 | 79 | 50 | 1 | 62 | 33 | 64 | 61 | 75 | 2.66 | -1.5 | 18 | 3,613 | s. | 22 | nw. | 19 | 5 | 14 | 11 | 6.2 | 0.0 | 0.0 |
| Cape Henry | 18 | 8 | 54 | 29.89 | 29.91 | ---- | 73.0 | ---- | 92 | 14 | 80 | 55 | 18 | 66 | 26 | 67 | 65 | 80 | 7.05 | +3.1 | 16 | 6,903 | sw. | 43 | nw. | 19 | 4 | 17 | 9 | 6.2 | 0.0 | 0.0 |
| Lynchburg | 681 | 153 | 188 | 29.18 | 29.90 | -.11 | 71.8 | -2.8 | 92 | 20 | 82 | 49 | 1 | 62 | 34 | 64 | 60 | 70 | 2.98 | -0.8 | 16 | 4,825 | w. | 36 | w. | 21 | 4 | 17 | 9 | 5.8 | 0.0 | 0.0 |
| Norfolk | 91 | 170 | 205 | 29.84 | 29.94 | -.06 | 73.8 | -0.6 | 89 | 13 | 82 | 57 | 8 | 65 | 23 | 67 | 64 | 76 | 7.84 | +3.6 | 17 | 8,346 | sw. | 46 | nw. | 19 | 2 | 17 | 11 | 6.6 | 0.0 | 0.0 |
| Richmond | 144 | 11 | 52 | 29.77 | 29.92 | -.09 | 72.8 | -1.3 | 91 | 14 | 82 | 51 | 1 | 64 | 34 | 66 | 63 | 76 | 7.19 | +3.3 | 16 | 5,170 | sw. | 40 | nw. | 19 | 9 | 11 | 10 | 5.4 | 0.0 | 0.0 |
| Wytheville | 2,304 | 49 | 55 | 27.60 | 29.91 | -.10 | 65.5 | -3.2 | 84 | 19 | 74 | 42 | 1 | 57 | 28 | 60 | 58 | 82 | 5.65 | +1.4 | 19 | 3,744 | w. | 25 | w. | 9 | 1 | 16 | 13 | 7.0 | 0.0 | 0.0 |
| *South Atlantic States* | | | | | | | 76.3 | -0.2 | | | | | | | | | | 77 | 3.63 | -1.2 | | | | | | | | | | 5.9 | | |
| Asheville | 2,253 | 70 | 84 | 27.63 | 29.91 | -.10 | 68.0 | -0.7 | 89 | 21 | 77 | 45 | 8 | 59 | 30 | 62 | 60 | 80 | 4.45 | +0.2 | 16 | 4,681 | se. | 24 | nw. | 9 | 5 | 13 | 12 | 6.2 | 0.0 | 0.0 |
| Charlotte | 779 | 55 | 62 | 29.12 | 29.94 | -.07 | 75.4 | -0.1 | 98 | 21 | 86 | 54 | 8 | 65 | 28 | 68 | 65 | 76 | 4.49 | +0.3 | 17 | 2,580 | sw. | 17 | w. | 23 | 6 | 13 | 11 | 6.3 | 0.0 | 0.0 |
| Hatteras | 11 | 11 | 50 | 29.94 | 29.95 | -.06 | 76.0 | +0.4 | 89 | 21 | 82 | 60 | 1 | 70 | 18 | 71 | 69 | 81 | 1.46 | -3.1 | 5 | 9,047 | sw. | 40 | nw. | 22 | 12 | 12 | 6 | 4.6 | 0.0 | 0.0 |
| Raleigh | 376 | 103 | 110 | 29.54 | 29.93 | -.08 | 74.8 | -0.9 | 95 | 20 | 84 | 54 | 8 | 66 | 27 | 68 | 65 | 76 | 6.06 | +1.3 | 14 | 5,259 | sw. | 31 | sw. | 11 | 4 | 15 | 11 | 6.6 | 0.0 | 0.0 |
| Wilmington | 78 | 81 | 91 | 29.90 | 29.98 | -.03 | 77.3 | +0.5 | 98 | 21 | 86 | 56 | 8 | 69 | 27 | 71 | 68 | 78 | 3.07 | -2.0 | 10 | 5,417 | sw. | 30 | nw. | 22 | 9 | 17 | 4 | 5.0 | 0.0 | 0.0 |
| Charleston | 48 | 11 | 92 | 29.94 | 29.99 | -.02 | 79.6 | +0.7 | 100 | 20 | 86 | 63 | 8 | 73 | 23 | 72 | 70 | 75 | 2.75 | -1.8 | 11 | 6,886 | sw. | 24 | nw. | 23 | 8 | 11 | 11 | 5.5 | 0.0 | 0.0 |
| Columbia, S. C | 351 | 41 | 57 | 29.59 | 29.96 | -.05 | 77.6 | -0.5 | 98 | 21 | 87 | 60 | 7 | 68 | 26 | 69 | 65 | 74 | 2.79 | -1.4 | 11 | 4,404 | s. | 30 | sw. | 23 | 8 | 16 | 6 | 5.3 | 0.0 | 0.0 |
| Due West | 711 | 10 | 55 | 29.22 | 29.98 | ---- | 75.9 | ---- | 94 | 21 | 84 | 52 | 8 | 66 | 29 | ---- | ---- | ---- | 3.89 | ---- | 17 | 5,924 | sw. | 26 | sw. | 5 | 7 | 11 | 12 | 6.3 | 0.0 | 0.0 |
| Greenville, S. C | 1,039 | 139 | 146 | 28.86 | 29.94 | ---- | 73.9 | -0.2 | 93 | 21 | 83 | 55 | 8 | 65 | 25 | 66 | 63 | 76 | 4.36 | ---- | 18 | 5,939 | sw. | 28 | sw. | 6 | 6 | 10 | 14 | 6.7 | 0.0 | 0.0 |
| Augusta | 182 | 62 | 77 | 29.76 | 29.95 | -.06 | 78.6 | -0.1 | 98 | 20 | 88 | 58 | 8 | 69 | 29 | 70 | 67 | 73 | 2.97 | -1.7 | 14 | 3,864 | s. | 30 | nw. | 23 | 6 | 10 | 14 | 6.1 | 0.0 | 0.0 |
| Savannah | 65 | 150 | 194 | 29.92 | 29.99 | -.02 | 78.6 | -0.4 | 96 | 20 | 88 | 63 | 8 | 70 | 26 | 71 | 68 | 78 | 4.15 | -1.1 | 14 | 7,147 | sw. | 36 | se. | 22 | 7 | 10 | 13 | 6.0 | 0.0 | 0.0 |
| Jacksonville | 43 | 209 | 245 | 29.96 | 30.01 | .00 | 79.0 | -0.9 | 95 | 20 | 88 | 64 | 17 | 70 | 24 | 71 | 68 | 77 | 4.10 | -1.2 | 12 | 6,480 | sw. | 38 | sw. | 2 | 7 | 13 | 10 | 5.7 | 0.0 | 0.0 |
| *Florida Peninsula* | | | | | | | 80.8 | -0.1 | | | | | | | | | | 76 | 6.63 | +0.1 | | | | | | | | | | 4.8 | | |
| Key West | 22 | 10 | 64 | 29.96 | 29.98 | -.01 | 82.6 | +0.7 | 90 | 15 | 88 | 70 | 28 | 77 | 14 | 76 | 73 | 76 | 2.61 | -1.6 | 11 | 5,343 | se. | 21 | ne. | 9 | 18 | 5 | 7 | 4.0 | 0.0 | 0.0 |
| Miami | 25 | 71 | 164 | 29.99 | 30.02 | ---- | 79.5 | -0.9 | 88 | 16 | 85 | 68 | 16 | 74 | 20 | 74 | 72 | 76 | 6.14 | -1.0 | 16 | 4,967 | se. | 35 | w. | 16 | 6 | 12 | 12 | 6.0 | 0.0 | 0.0 |
| Tampa | 35 | 79 | 87 | 29.98 | 30.01 | .00 | 80.2 | 0.0 | 93 | 13 | 90 | 64 | 21 | 71 | 28 | 73 | 70 | 75 | 11.13 | +2.8 | 15 | 3,392 | e. | 34 | se. | 21 | 4 | 23 | 3 | 5.1 | 0.0 | 0.0 |
| Titusville | 44 | 5 | ---- | 29.97 | 30.02 | ---- | 79.1 | ---- | 95 | 30 | 90 | 62 | 9 | 69 | 25 | ---- | ---- | ---- | 5.82 | ---- | 11 | ---- | s. | ---- | ---- | ---- | 15 | 8 | 7 | 4.2 | 0.0 | 0.0 |
| *East Gulf States* | | | | | | | 77.2 | -1.3 | | | | | | | | | | 78 | 8.40 | +4.0 | | | | | | | | | | 6.0 | | |
| Atlanta | 1,173 | 190 | 216 | 28.75 | 29.96 | -.05 | 74.1 | -1.9 | 90 | 20 | 82 | 59 | 7 | 66 | 22 | 66 | 63 | 72 | 5.75 | +2.0 | 15 | 6,276 | w. | 32 | nw. | 22 | 4 | 4 | 22 | 7.6 | 0.0 | 0.0 |
| Macon | 370 | 78 | 87 | 29.58 | 29.96 | -.05 | 77.6 | -1.3 | 96 | 20 | 87 | 55 | 8 | 68 | 32 | 70 | 68 | 78 | 4.41 | +0.8 | 14 | 3,996 | s. | 21 | w. | 23 | 7 | 9 | 14 | 6.1 | 0.0 | 0.0 |
| Thomasville | 273 | 49 | 58 | 29.69 | 29.98 | -.02 | 78.6 | -0.9 | 95 | 20 | 88 | 61 | 8 | 69 | 27 | 71 | 69 | 78 | 4.94 | +0.2 | 12 | 2,642 | sw. | 19 | sw. | 16 | 3 | 12 | 15 | 6.7 | 0.0 | 0.0 |
| Apalachicola | 36 | 42 | 49 | 29.95 | 29.99 | ---- | 78.8 | ---- | 90 | 21 | 85 | 66 | 7 | 73 | 18 | 74 | 72 | 79 | 5.42 | ---- | 9 | 4,153 | sw. | 25 | ne. | 24 | 13 | 8 | 9 | 4.5 | 0.0 | 0.0 |
| Pensacola | 56 | 149 | 185 | 29.91 | 29.97 | -.02 | 78.6 | -0.7 | 88 | 21 | 83 | 68 | 14 | 74 | 14 | 73 | 71 | 78 | 4.60 | -0.1 | 12 | 8,602 | s. | 36 | s. | 3 | 7 | 11 | 12 | 6.0 | 0.0 | 0.0 |
| Anniston | 741 | 9 | 57 | 29.20 | 29.97 | -.03 | 74.4 | -0.6 | 92 | 20 | 84 | 54 | 8 | 65 | 32 | ---- | ---- | ---- | 8.70 | +4.8 | 16 | 3,056 | sw. | 23 | sw. | 13 | 8 | 11 | 11 | 5.5 | 0.0 | 0.0 |
| Birmingham | 700 | 11 | 48 | 29.20 | 29.95 | -.04 | 75.0 | -2.9 | 91 | 19 | 83 | 59 | 6 | 67 | 22 | 69 | 66 | 79 | 8.84 | +5.0 | 16 | 4,737 | s. | 25 | nw. | 13 | 4 | 16 | 10 | 6.3 | 0.0 | 0.0 |
| Mobile | 57 | 125 | 161 | 29.90 | 29.96 | -.03 | 78.7 | -1.6 | 92 | 22 | 85 | 64 | 7 | 72 | 21 | 73 | 71 | 81 | 7.13 | +1.7 | 13 | 6,648 | s. | 33 | w. | 5 | 4 | 15 | 11 | 5.9 | 0.0 | 0.0 |
| Montgomery | 223 | 100 | 112 | 29.72 | 29.96 | -.04 | 77.2 | -2.4 | 92 | 20 | 85 | 63 | 7 | 69 | 23 | 71 | 68 | 77 | 15.59 | +11.8 | 16 | 4,194 | sw. | 31 | nw. | 30 | 4 | 11 | 15 | 7.0 | 0.0 | 0.0 |
| Corinth | 469 | 6 | ---- | ---- | ---- | ---- | 75.8 | ---- | 91 | 19 | 84 | 56 | 7 | 67 | 26 | ---- | ---- | ---- | 7.68 | ---- | 15 | ---- | s. | ---- | ---- | ---- | 1 | 26 | 3 | ---- | 0.0 | 0.0 |
| Meridian | 375 | 87 | 95 | 29.54 | 29.92 | -.06 | 77.6 | -0.5 | 93 | 30 | 86 | 59 | 7 | 69 | 26 | 71 | 68 | 76 | 10.01 | +5.4 | 11 | 4,219 | sw. | 31 | sw. | 1 | 5 | 15 | 10 | 6.1 | 0.0 | 0.0 |
| Vicksburg | 247 | 65 | 73 | 29.65 | 29.92 | -.05 | 77.4 | -1.6 | 91 | 30 | 85 | 62 | 6 | 70 | 24 | 71 | 69 | 79 | 9.76 | +5.8 | 11 | 4,562 | s. | 22 | sw. | 1 | 8 | 11 | 11 | 5.7 | 0.0 | 0.0 |
| New Orleans | 53 | 76 | 84 | 29.89 | 29.94 | -.04 | 80.3 | -0.3 | 93 | 30 | 88 | 67 | 5 | 73 | 19 | 74 | 72 | 78 | 12.68 | +6.8 | 11 | 3,947 | sw. | 20 | sw. | 3 | 9 | 14 | 7 | 5.1 | 0.0 | 0.0 |
| *West Gulf States* | | | | | | | 78.5 | -1.3 | | | | | | | | | | 77 | 5.31 | +1.9 | | | | | | | | | | 4.8 | | |
| Shreveport | 249 | 77 | 93 | 29.60 | 29.86 | -.10 | 78.2 | -2.5 | 96 | 30 | 87 | 61 | 6 | 70 | 26 | 71 | 68 | 76 | 3.30 | -0.2 | 8 | 4,624 | s. | 36 | sw. | 23 | 8 | 13 | 9 | 5.3 | 0.0 | 0.0 |
| Bentonville | 1,303 | 11 | 44 | 28.47 | 29.81 | -.13 | 68.7 | -5.4 | 87 | 18 | 77 | 48 | 6 | 61 | 27 | ---- | ---- | ---- | 13.81 | ---- | 19 | ---- | s. | ---- | ---- | ---- | 12 | 11 | 7 | ---- | 0.0 | 0.0 |
| Fort Smith | 457 | 79 | 94 | 29.34 | 29.82 | -.12 | 74.1 | -3.4 | 91 | 29 | 82 | 53 | 6 | 66 | 28 | 68 | 65 | 76 | 7.22 | +3.5 | 14 | 5,600 | e | 32 | sw. | 20 | 4 | 13 | 13 | 6.6 | 0.0 | 0.0 |
| Little Rock | 357 | 136 | 153 | 29.49 | 29.85 | -.11 | 74.8 | -2.6 | 90 | 20 | 83 | 53 | 6 | 66 | 28 | 69 | 66 | 77 | 6.72 | +2.6 | 15 | 6,023 | s. | 37 | nw. | 21 | 6 | 9 | 15 | 6.6 | 0.0 | 0.0 |
| Austin | 605 | 136 | 148 | 29.18 | 29.81 | ---- | 80.6 | -0.6 | 97 | 29 | 90 | 57 | 6 | 71 | 33 | 73 | 70 | 74 | 3.02 | +0.6 | 7 | 7,423 | s. | 35 | s. | 10 | 10 | 14 | 6 | 5.0 | 0.0 | 0.0 |
| Brownsville | 57 | 53 | 61 | 29.74 | 29.80 | ---- | 82.6 | +0.2 | 94 | 25 | 89 | 69 | 2 | 76 | 19 | 76 | 75 | 83 | 2.68 | -0.2 | 5 | 6,876 | s. | 23 | s. | 18 | 19 | 11 | 0 | 2.7 | 0.0 | 0.0 |
| Corpus Christi | 20 | 11 | 78 | 29.81 | 29.83 | -.00 | 81.4 | +0.4 | 90 | 29 | 87 | 69 | 4 | 76 | 18 | 77 | 75 | 85 | 6.99 | +4.2 | 4 | 11,262 | se. | 30 | se. | 18 | 11 | 14 | 5 | 4.5 | 0.0 | 0.0 |
| Dallas | 512 | 220 | 227 | 29.28 | 29.81 | ---- | 77.6 | ---- | 95 | 22 | 87 | 54 | 5 | 68 | 26 | ---- | ---- | ---- | 3.74 | ---- | 11 | 9,692 | s. | 56 | sw. | 3 | 9 | 17 | 4 | 4.4 | 0.0 | 0.0 |
| Fort Worth | 670 | 106 | 114 | 29.09 | 29.78 | -.13 | 78.7 | -1.2 | 97 | 28 | 89 | 56 | 5 | 68 | 30 | 70 | 66 | 70 | 11.58 | +8.5 | 11 | 8,384 | s. | 35 | se. | 2 | 7 | 18 | 5 | 5.3 | 0.0 | 0.0 |
| Galveston | 54 | 106 | 114 | 29.84 | 29.90 | -.05 | 80.3 | -0.4 | 88 | 25 | 84 | 66 | 26 | 77 | 20 | 75 | 74 | 82 | 4.23 | -0.1 | 7 | 8,770 | s. | 35 | se. | 15 | 11 | 17 | 2 | 4.2 | 0.0 | 0.0 |
| Groesbeck | 461 | 11 | 56 | 29.35 | 29.82 | ---- | 78.6 | ---- | 94 | 22 | 88 | 56 | 5 | 70 | 27 | ---- | ---- | ---- | 7.71 | ---- | 11 | 8,953 | s. | 36 | nw. | 4 | 11 | 13 | 6 | 4.9 | 0.0 | 0.0 |
| Houston | 138 | 292 | 314 | 29.73 | 29.87 | ---- | 80.1 | -1.3 | 93 | 30 | 88 | 65 | 6 | 72 | 25 | ---- | ---- | ---- | 4.71 | +0.4 | 12 | 8,747 | se. | 35 | n. | 26 | 11 | 13 | 6 | 4.7 | 0.0 | 0.0 |
| Palestine | 510 | 64 | 72 | 29.32 | 29.84 | -.10 | 78.2 | -0.8 | 93 | 1 | 87 | 55 | 5 | 69 | 30 | 71 | 69 | 77 | 7.07 | +3.4 | 12 | 6,014 | s. | 25 | sw. | 2 | 12 | 11 | 7 | 4.6 | 0.0 | 0.0 |
| Port Arthur | 34 | 58 | 66 | 29.85 | 29.89 | ---- | 80.0 | | 89 | 21 | 86 | 63 | 14 | 74 | 24 | 75 | 73 | 80 | 5.90 | ---- | 11 | 7,266 | s. | 42 | n. | 14 | 16 | 10 | 4 | 4.1 | 0.0 | 0.0 |
| San Antonio | 693 | 119 | 132 | 29.09 | 29.80 | -.10 | 81.8 | +0.8 | 99 | 28 | 92 | 60 | 6 | 72 | 28 | 72 | 68 | 70 | 3.29 | +0.8 | 4 | 5,815 | se. | 27 | ne. | 10 | 9 | 19 | 2 | 4.4 | 0.0 | 0.0 |
| Taylor | 583 | 55 | 63 | 29.25 | 29.86 | -0.6 | 80.4 | +0.4 | 97 | 29 | 90 | 57 | 5 | 71 | 28 | ---- | ---- | ---- | 2.88 | -0.6 | 6 | 7,949 | s. | 28 | s. | 12 | 13 | 13 | 4 | 4.5 | 0.0 | 0.0 |

TABLE I.—*Climatological data for Weather Bureau stations, June, 1928*—Continued

| District and station | Elevation of instruments: Barometer above sea level | Elevation of instruments: Thermometer above ground | Elevation of instruments: Anemometer above ground | Pressure: Station reduced to mean of 24 hours | Pressure: Sea level, reduced to mean of 24 hours | Pressure: Departure from normal | Temperature of the air: Mean max. + mean min. ÷ 2 | Temperature of the air: Departure from normal | Temperature of the air: Maximum | Temperature of the air: Date | Temperature of the air: Mean maximum | Temperature of the air: Minimum | Temperature of the air: Date | Temperature of the air: Mean minimum | Temperature of the air: Greatest daily range | Mean wet thermometer | Mean temperature of the dew point | Mean relative humidity | Precipitation: Total | Precipitation: Departure from normal | Precipitation: Days with .01, or more | Wind: Total movement | Wind: Prevailing direction | Wind: Maximum velocity: Miles per hour | Wind: Maximum velocity: Direction | Wind: Maximum velocity: Date | Clear days | Partly cloudy days | Cloudy days | Average cloudiness, tenths | Total snowfall | Snow, sleet, and ice on ground at end of month |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Ohio Valley and Tennessee* | Ft. | Ft. | Ft. | In. | In. | In. | °F. 68.5 | °F. -4.3 | °F. | | °F. | °F. | | °F. | °F. | °F. | °F. | % 77 | In. 8.50 | In. +4.5 | | Miles | | | | | | | | 0-10 7.2 | In. | In. |
| Chattanooga | 762 | 190 | 215 | 29.12 | 29.92 | -0.08 | 72.9 | -2.5 | 90 | 19 | 81 | 54 | 8 | 65 | 29 | 66 | 64 | 77 | 7.69 | +3.5 | 21 | 5,286 | sw. | 36 | nw. | 20 | 1 | 15 | 14 | 6.9 | 0.0 | 0.0 |
| Knoxville | 995 | 102 | 111 | 28.89 | 29.92 | -.08 | 71.9 | -2.1 | 93 | 19 | 81 | 51 | 8 | 63 | 30 | 65 | 62 | 77 | 11.33 | +7.7 | 19 | 4,813 | sw. | 36 | sw. | 29 | 0 | 10 | 20 | 7.9 | 0.0 | 0.0 |
| Memphis | 399 | 76 | 97 | 29.45 | 29.86 | -.11 | 74.2 | -3.4 | 89 | 18 | 82 | 56 | 6 | 67 | 19 | 69 | 66 | 78 | 3.96 | +0.4 | 16 | 5,412 | sw. | 38 | n. | 9 | 1 | 12 | 17 | 7.2 | 0.0 | 0.0 |
| Nashville | 546 | 168 | 191 | 29.34 | 29.91 | -.08 | 71.7 | -3.9 | 90 | 19 | 79 | 54 | 7 | 64 | 24 | 66 | 62 | 75 | 11.64 | +7.6 | 13 | 5,991 | w. | 35 | nw. | 22 | 2 | 11 | 17 | 7.0 | 0.0 | 0.0 |
| Lexington | 989 | 193 | 230 | 28.85 | 29.90 | -.10 | 67.2 | -5.0 | 85 | 19 | 75 | 50 | 6 | 59 | 25 | | | | 10.62 | +6.6 | 21 | 8,515 | sw. | 36 | ne. | 19 | 4 | 13 | 13 | 6.8 | 0.0 | 0.0 |
| Louisville | 525 | 188 | 234 | 29.31 | 29.89 | -.09 | 69.1 | -5.6 | 86 | 19 | 77 | 53 | 3 | 61 | 25 | 64 | 61 | 78 | 7.25 | +3.4 | 17 | 6,826 | s. | 29 | w. | 13 | 1 | 17 | 12 | 7.0 | 0.0 | 0.0 |
| Evansville | 431 | 76 | 116 | 29.42 | 29.88 | -.09 | 69.8 | -5.3 | 87 | 19 | 77 | 54 | 10 | 62 | 24 | 64 | 61 | 76 | 9.78 | +5.7 | 20 | 6,003 | w. | 30 | sw. | 18 | 1 | 11 | 18 | 7.7 | 0.0 | 0.0 |
| Indianapolis | 822 | 194 | 230 | 28.98 | 29.86 | -.11 | 65.4 | -6.2 | 86 | 12 | 73 | 49 | 4 | 57 | 31 | 59 | 56 | 75 | 8.77 | +5.2 | 18 | 6,887 | s. | 44 | w. | 19 | 4 | 11 | 15 | 7.1 | 0.0 | 0.0 |
| Royal Center | 736 | 11 | 55 | 29.04 | 29.83 | | 62.8 | | 84 | 12 | 72 | 42 | 3 | 53 | 31 | | | | 6.26 | | 16 | 6,428 | w. | 38 | w. | 19 | 2 | 10 | 18 | 7.2 | 0.0 | 0.0 |
| Terre Haute | 575 | 96 | 129 | 29.24 | 29.85 | | 66.8 | | 86 | 19 | 75 | 50 | 4 | 59 | 26 | 62 | 59 | 80 | 6.88 | | 20 | 5,760 | s. | 27 | s. | 8 | 2 | 14 | 14 | 7.2 | 0.0 | 0.0 |
| Cincinnati | 627 | 11 | 51 | 29.21 | 29.88 | -.11 | 67.0 | -4.2 | 86 | 19 | 76 | 46 | 3 | 58 | 31 | 62 | 58 | 78 | 9.07 | +5.4 | 19 | 4,451 | sw. | 25 | nw. | 19 | 3 | 9 | 18 | 7.3 | 0.0 | 0.0 |
| Columbus | 822 | 179 | 222 | 29.02 | 29.88 | -.11 | 65.7 | -5.2 | 84 | 13 | 74 | 46 | 10 | 58 | 26 | 60 | 56 | 75 | 6.94 | +3.6 | 18 | 5,700 | s. | 37 | w. | 19 | 6 | 11 | 13 | 6.7 | 0.0 | 0.0 |
| Dayton | 899 | 137 | 173 | 28.92 | 29.86 | | 65.8 | -5.6 | 85 | 19 | 74 | 45 | 3 | 57 | 31 | 60 | 56 | 75 | 7.13 | +3.3 | 21 | 5,819 | sw. | 33 | sw. | 19 | 3 | 14 | 13 | 7.0 | 0.0 | 0.0 |
| Elkins | 1,947 | 59 | 67 | 27.90 | 29.91 | -.09 | 64.1 | -2.8 | 84 | 13 | 74 | 38 | 1 | 54 | 33 | 59 | 57 | 83 | 7.99 | +3.0 | 25 | 3,188 | w. | 30 | nw. | 9 | 0 | 9 | 21 | 8.0 | 0.0 | 0.0 |
| Parkersburg | 637 | 77 | 82 | 29.26 | 29.91 | -.09 | 68.2 | -3.2 | 89 | 13 | 77 | 49 | 1 | 60 | 28 | 62 | 59 | 75 | 8.63 | +4.0 | 21 | 3,674 | se. | 24 | nw. | 19 | 5 | 5 | 20 | 7.2 | 0.0 | 0.0 |
| Pittsburgh | 842 | 353 | 410 | 28.98 | 29.87 | -.12 | 66.1 | -4.6 | 86 | 13 | 74 | 46 | 3 | 58 | 28 | 60 | 56 | 73 | 7.73 | +3.9 | 20 | 6,454 | sw | 36 | nw. | 19 | 3 | 5 | 22 | 7.6 | 0.0 | 0.0 |
| *Lower Lake Region* | | | | | | | 62.9 | -3.9 | | | | | | | | | | 71 | 4.88 | +1.5 | | | | | | | | | | 6.4 | | |
| Buffalo | 767 | 247 | 280 | 29.03 | 29.85 | -.12 | 61.6 | -2.8 | 83 | 12 | 68 | 44 | 3 | 55 | 30 | 58 | 56 | 86 | 9.67 | +6.8 | 18 | 8,632 | sw. | 36 | sw. | 2 | 6 | 12 | 12 | 6.3 | 0.0 | 0.0 |
| Canton | 448 | 10 | 61 | 29.38 | 29.85 | | 61.4 | -4.4 | 85 | 13 | 71 | 39 | 4 | 52 | 31 | | | | 4.21 | +0.8 | 13 | 5,418 | sw. | 27 | sw. | 2 | 13 | 7 | 10 | 5.2 | 0.0 | 0.0 |
| Ithaca | 836 | 5 | 100 | 28.96 | 29.85 | | 62.5 | | 84 | 25 | 72 | 41 | 11 | 53 | 37 | 58 | 54 | 76 | 5.86 | +2.3 | 19 | 5,540 | se. | 25 | s. | 1 | 4 | 11 | 15 | 6.6 | 0.0 | 0.0 |
| Oswego | 335 | 76 | 91 | 29.50 | 29.86 | -.11 | 60.7 | -4.1 | 86 | 13 | 68 | 42 | 3 | 53 | 28 | 57 | 54 | 77 | 3.67 | +0.5 | 18 | 4,819 | se. | 19 | se. | 20 | 5 | 6 | 19 | 6.9 | 0.0 | 0.0 |
| Rochester | 523 | 86 | 102 | 29.30 | 29.86 | -.11 | 63.4 | -2.7 | 91 | 13 | 72 | 42 | 3 | 55 | 28 | 57 | 53 | 72 | 4.63 | +1.6 | 19 | 4,412 | sw. | 18 | w. | 10 | 7 | 9 | 14 | 6.4 | 0.0 | 0.0 |
| Syracuse | 597 | 97 | 113 | 29.24 | 29.88 | -.09 | 63.1 | -3.8 | 83 | 25 | 71 | 44 | 3 | 55 | 28 | | | | 3.96 | +0.1 | 17 | 6,043 | s. | 27 | s. | 13 | 4 | 11 | 15 | 6.9 | 0.0 | 0.0 |
| Erie | 714 | 130 | 166 | 29.10 | 29.86 | -.12 | 63.2 | -3.0 | 89 | 13 | 71 | 45 | 3 | 56 | 24 | 58 | 54 | 74 | 3.96 | +0.6 | 18 | 7,357 | w. | 36 | sw. | 23 | 12 | 11 | 7 | 5.1 | 0.0 | 0.0 |
| Cleveland | 762 | 190 | 201 | 29.04 | 29.85 | -.13 | 64.0 | -3.1 | 85 | 13 | 71 | 45 | 3 | 57 | 25 | 58 | 54 | 72 | 4.60 | +1.6 | 17 | 6,837 | sw. | 34 | w. | 29 | 7 | 8 | 15 | 6.6 | 0.0 | 0.0 |
| Sandusky | 629 | 5 | 67 | 29.18 | 29.85 | -.13 | 64.6 | -4.2 | 85 | 22 | 73 | 44 | 3 | 56 | 30 | | | | 5.26 | +1.8 | 15 | 5,435 | sw. | 22 | nw. | 29 | 5 | 10 | 15 | 6.7 | 0.0 | 0.0 |
| Toledo | 628 | 208 | 243 | 29.18 | 29.85 | -.12 | 63.6 | -5.1 | 84 | 22 | 71 | 44 | 10 | 56 | 26 | 58 | 55 | 75 | 3.89 | +0.6 | 15 | 8,240 | sw. | 36 | sw. | 13 | 8 | 12 | 10 | 5.9 | 0.0 | 0.0 |
| Fort Wayne | 856 | 113 | 124 | 28.93 | 29.84 | | 63.3 | -5.2 | 84 | 22 | 72 | 43 | 10 | 55 | 29 | 58 | 55 | 76 | 3.85 | | 12 | 5,652 | sw. | 26 | sw. | 13 | 7 | 8 | 15 | 7.0 | 0.0 | 0.0 |
| Detroit | 730 | 218 | 258 | 29.06 | 29.84 | -.13 | 63.4 | -4.0 | 84 | 21 | 72 | 44 | 10 | 55 | 29 | 58 | 55 | 77 | 3.83 | +0.3 | 12 | 6,264 | sw. | 30 | sw. | 13 | 3 | 10 | 17 | 7.2 | 0.0 | 0.0 |
| *Upper Lake Region* | | | | | | | 58.6 | -4.0 | | | | | | | | | | 74 | 5.05 | +1.8 | | | | | | | | | | 6.4 | | |
| Alpena | 609 | 13 | 92 | 29.18 | 29.84 | -.12 | 57.5 | -2.9 | 82 | 13 | 67 | 36 | 3 | 48 | 31 | 53 | 49 | 72 | 2.85 | -0.4 | 12 | 6,890 | se. | 28 | e. | 18 | 9 | 12 | 9 | 5.7 | 0.0 | 0.0 |
| Escanaba | 612 | 54 | 60 | 29.16 | 29.82 | -.12 | 57.1 | -3.6 | 82 | 27 | 65 | 40 | 2 | 49 | 28 | 52 | 47 | 73 | 1.95 | -1.3 | 11 | 6,641 | s. | 29 | n. | 9 | 5 | 11 | 14 | 6.4 | 0.0 | 0.0 |
| Grand Haven | 632 | 54 | 89 | 29.14 | 29.82 | -.14 | 58.6 | -5.1 | 82 | 12 | 67 | 38 | 3 | 50 | 29 | 54 | 50 | 76 | 5.15 | +2.2 | 13 | 6,502 | w. | 28 | s. | 13 | 7 | 7 | 16 | 6.5 | 0.0 | 0.9 |
| Grand Rapids | 707 | 70 | 87 | 29.07 | 29.84 | -.13 | 61.9 | -5.9 | 82 | 17 | 71 | 43 | 3 | 53 | 27 | 56 | 51 | 71 | 8.03 | +4.6 | 13 | 3,735 | w. | 16 | w. | 1 | 5 | 10 | 15 | 6.9 | 0.0 | 0.0 |
| Houghton | 668 | 64 | 99 | 29.10 | 29.82 | -.12 | 55.3 | -4.7 | 81 | 30 | 64 | 37 | 4 | 46 | 35 | | | | 3.15 | -0.3 | 13 | 6,375 | e. | 40 | n. | 24 | 5 | 10 | 15 | 6.8 | 0.0 | 0.0 |
| Lansing | 878 | 6 | 49 | 28.90 | 29.83 | | 60.3 | -6.1 | 81 | 13 | 70 | 36 | 3 | 51 | 30 | 57 | 54 | 79 | 3.12 | -0.4 | 12 | 3,250 | s. | 15 | nw. | 9 | 10 | 7 | 13 | 6.0 | 0.0 | 0.0 |
| Ludington | 637 | 60 | 66 | 29.13 | 29.83 | | 56.5 | | 80 | 12 | 64 | 38 | 3 | 49 | 26 | 52 | 48 | 76 | 3.29 | | 14 | 5,948 | s. | 25 | s. | 12 | 9 | 10 | 11 | 5.6 | 0.0 | 0.0 |
| Marquette | 734 | 77 | 111 | 29.04 | 29.84 | -.10 | 55.2 | -3.7 | 80 | 27 | 63 | 38 | 4 | 47 | 29 | 50 | 47 | 76 | 8.48 | +5.3 | 16 | 5,107 | w. | 34 | se. | 12 | 3 | 10 | 17 | 7.2 | 0.0 | 0.9 |
| Port Huron | 638 | 70 | 120 | 29.15 | 29.84 | -.13 | 61.0 | -3.2 | 81 | 13 | 69 | 39 | 3 | 53 | 29 | 57 | 53 | 77 | 5.64 | +2.9 | 11 | 6,518 | sw. | 32 | nw. | 29 | 4 | 16 | 10 | 5.8 | 0.0 | 0.0 |
| Sault Ste. Marie | 614 | 11 | 52 | 29.16 | 29.85 | -.11 | 56.6 | -2.0 | 79 | 28 | 67 | 33 | 4 | 46 | 34 | 51 | 46 | 72 | 2.12 | -0.6 | 11 | 4,662 | w. | 26 | nw. | 21 | 8 | 11 | 11 | 5.9 | 0.0 | 0.0 |
| Chicago | 673 | 7 | 131 | 29.11 | 29.83 | -.13 | 63.0 | -4.3 | 86 | 12 | 71 | 46 | 10 | 55 | 25 | 57 | 53 | 75 | 6.97 | +3.7 | 14 | 6,568 | ne. | 30 | sw. | 13 | 5 | 9 | 16 | 6.9 | 0.0 | 0.0 |
| Green Bay | 617 | 109 | 141 | 29.16 | 29.81 | -.14 | 60.6 | -4.3 | 84 | 30 | 70 | 42 | 10 | 51 | 28 | 54 | 49 | 68 | 5.50 | +2.0 | 13 | 7,097 | s. | 35 | s. | 13 | 4 | 12 | 14 | 6.7 | 0.0 | 0.0 |
| Milwaukee | 681 | 125 | 221 | 29.10 | 29.83 | -.12 | 60.0 | -3.9 | 85 | 30 | 68 | 45 | 5 | 52 | 30 | 54 | 50 | 74 | 6.95 | +3.6 | 14 | 8,081 | se. | 38 | sw. | 13 | 6 | 7 | 17 | 6.7 | 0.0 | 0.0 |
| Duluth | 1,133 | 5 | 47 | 28.63 | 29.84 | -.08 | 55.2 | -2.0 | 84 | 29 | 65 | 35 | 3 | 45 | 34 | 50 | 46 | 76 | 5.72 | +1.8 | 17 | 7,214 | ne. | 38 | ne. | 18 | 7 | 9 | 14 | 6.7 | 0.0 | 0.0 |
| *North Dakota* | | | | | | | 58.9 | -4.4 | | | | | | | | | | 67 | 4.42 | +0.8 | | | | | | | | | | 5.9 | | |
| Moorhead | 940 | 50 | 58 | 28.81 | 29.81 | -.09 | 60.2 | -4.2 | 85 | 29 | 72 | 35 | 2 | 49 | 35 | 53 | 47 | 64 | 3.13 | -0.9 | 11 | 4,969 | n. | 22 | nw. | 13 | 8 | 6 | 16 | 6.3 | 0.0 | 0.0 |
| Bismarck | 1,674 | 8 | 57 | 28.06 | 29.82 | -.05 | 59.4 | -4.3 | 84 | 30 | 70 | 38 | 9 | 48 | 33 | 53 | 47 | 68 | 4.81 | +1.5 | 16 | 5,214 | e. | 40 | ne. | 12 | 10 | 10 | 10 | 5.9 | 0.0 | 0.0 |
| Devils Lake | 1,478 | 11 | 44 | 28.27 | 29.82 | -.01 | 57.6 | -5.0 | 83 | 29 | 68 | 35 | 3 | 47 | 33 | 52 | 47 | 71 | 5.17 | +1.6 | 14 | 5,105 | n. | 27 | n. | 12 | 10 | 9 | 11 | 5.2 | 0.0 | 0.0 |
| Ellendale | 1,457 | 10 | 56 | 28.27 | 29.82 | | 59.2 | | 83 | 16 | 71 | 34 | 3 | 48 | 38 | | | | 5.63 | | 12 | 7,762 | nw. | 40 | ne. | 12 | 3 | 17 | 10 | 6.5 | 0.0 | 0.0 |
| Grand Forks | 833 | 12 | 67 | | | | 59.2 | | 84 | 29 | 70 | 31 | 2 | 48 | 40 | 54 | | | 5.08 | | 14 | | nw. | | | | 9 | 13 | 8 | | 0.0 | 0.0 |
| Williston | 1,878 | 41 | 48 | 27.87 | 29.82 | -.04 | 58.4 | -4.3 | 80 | 29 | 69 | 36 | 9 | 48 | 33 | 51 | 45 | 65 | 4.56 | +1.1 | 16 | 4,113 | se. | 24 | n. | 12 | 8 | 13 | 9 | 5.6 | 0.0 | 0.0 |
| *Upper Mississippi Valley* | | | | | | | 65.5 | -5.0 | | | | | | | | | | 70 | 5.54 | +1.4 | | | | | | | | | | 6.8 | | |
| Minneapolis | 918 | 102 | 208 | 28.84 | 29.80 | | 62.6 | -4.9 | 82 | 29 | 71 | 45 | 2 | 54 | 28 | | | | 2.59 | -1.6 | 13 | 7,182 | nw. | 34 | nw. | 1 | 6 | 7 | 17 | 7.0 | 0.0 | 0.0 |
| St. Paul | 837 | 236 | 261 | 28.91 | 29.80 | -.12 | 61.8 | -5.3 | 82 | 29 | 71 | 43 | 10 | 53 | 29 | | | | 2.60 | -1.5 | 14 | 7,442 | se. | 37 | sw. | 1 | 7 | 7 | 16 | 6.6 | 0.0 | 0.0 |
| La Crosse | 714 | 11 | 48 | 29.05 | 29.81 | -.12 | 63.0 | -5.3 | 85 | 30 | 73 | 39 | 10 | 53 | 35 | 56 | 51 | 68 | 3.25 | -0.8 | 8 | 2,562 | nw. | 15 | nw. | 1 | 5 | 8 | 17 | 7.0 | 0.0 | 0.0 |
| Madison | 974 | 70 | 78 | 28.80 | 29.82 | -.12 | 62.5 | -4.7 | 83 | 12 | 70 | 45 | 2 | 54 | 25 | 56 | 51 | 69 | 6.33 | +2.6 | 11 | 5,101 | n. | 25 | ne. | 19 | 4 | 13 | 13 | 7.1 | 0.0 | 0.0 |
| Wausau | 1,247 | 4 | | 28.50 | 29.82 | | 59.3 | | 86 | 30 | 69 | 37 | 2 | 49 | 37 | | | | 3.28 | | 13 | | nw. | | | | 7 | 7 | 16 | 6.7 | 0.0 | 0.0 |
| Charles City | 1,015 | 10 | 51 | 28.77 | 29.83 | -.08 | 62.8 | -3.7 | 84 | 20 | 73 | 41 | 10 | 53 | 33 | 56 | 50 | 65 | 2.85 | -2.2 | 10 | 4,039 | nw. | 22 | sw. | 12 | 6 | 13 | 11 | 5.7 | 0.0 | 0.0 |
| Davenport | 606 | 71 | 79 | 29.17 | 29.82 | -.12 | 66.7 | -3.8 | 84 | 18 | 76 | 49 | 5 | 58 | 27 | 59 | 55 | 69 | 4.55 | +0.4 | 14 | 4,405 | nw. | 34 | se. | 7 | 3 | 13 | 14 | 7.2 | 0.0 | 0.0 |
| Des Moines | 861 | 84 | 97 | 28.92 | 29.81 | -.11 | 66.2 | -4.4 | 86 | 20 | 75 | 48 | 2 | 57 | 30 | 59 | 53 | 68 | 6.62 | +1.9 | 15 | 4,314 | n. | 35 | sw. | 12 | 4 | 10 | 16 | 7.0 | 0.0 | 0.0 |
| Dubuque | 700 | 81 | 96 | 29.07 | 29.81 | -.12 | 64.5 | -4.9 | 83 | 12 | 74 | 46 | 10 | 56 | 27 | 57 | 52 | 66 | 3.87 | -0.4 | 13 | 4,226 | nw. | 26 | sw. | 12 | 4 | 8 | 18 | 7.3 | 0.0 | 0.0 |
| Keokuk | 614 | 64 | 78 | 29.17 | 29.83 | -.11 | 66.8 | -5.7 | 85 | 21 | 76 | 50 | 6 | 58 | 26 | 60 | 55 | 69 | 5.15 | +1.0 | 12 | 4,477 | nw. | 26 | s. | 12 | 4 | 7 | 19 | 7.4 | 0.0 | 0.0 |
| Cairo | 358 | 87 | 93 | 29.49 | 29.86 | -.11 | 70.8 | -5.5 | 87 | 19 | 78 | 55 | 7 | 63 | 23 | 65 | 63 | 79 | 15.70 | +11.9 | 19 | 5,451 | s. | 28 | s. | 8 | 1 | 12 | 17 | 7.7 | 0.0 | 0.0 |
| Peoria | 609 | 11 | 45 | 29.19 | 29.85 | -.10 | 66.0 | -4.9 | 85 | 12 | 76 | 44 | 10 | 56 | 31 | 60 | 56 | 73 | 6.60 | +2.8 | 14 | 3,851 | nw. | 27 | se. | 8 | 7 | 15 | 8 | 5.7 | 0.0 | 0.0 |
| Springfield, Ill | 636 | 10 | 91 | 29.16 | 29.82 | -.13 | 67.4 | -4.8 | 86 | 19 | 76 | 51 | 6 | 59 | 28 | 61 | 57 | 71 | 5.06 | +1.0 | 17 | 5,272 | w. | 28 | nw. | 19 | 5 | 14 | 11 | 6.3 | 0.0 | 0.0 |
| Hannibal | 534 | 74 | 109 | 29.25 | 29.82 | -.13 | 67.0 | -5.5 | 85 | 18 | 76 | 50 | 2 | 58 | 27 | | | | 5.08 | +1.6 | 14 | 5,357 | sw. | 29 | w. | 19 | 2 | 12 | 16 | 7.1 | 0.0 | 0.0 |
| St. Louis | 568 | 265 | 303 | 29.24 | 29.84 | -.11 | 68.6 | -6.2 | 88 | 19 | 77 | 51 | 6 | 60 | 24 | 62 | 59 | 73 | 7.25 | +3.4 | 12 | 7,748 | s. | 43 | w. | 17 | 4 | 13 | 13 | 6.5 | 0.0 | 0.0 |
| *Missouri Valley* | | | | | | | 66.0 | -4.8 | | | | | | | | | | 69 | 6.34 | +20 | | | | | | | | | | 6.0 | | |
| Columbia, Mo | 784 | 6 | 84 | 29.00 | 29.82 | -.13 | 66.6 | -6.2 | 85 | 18 | 75 | 47 | 6 | 58 | 27 | | | | 14.86 | +10.5 | 19 | 4,466 | nw. | 19 | e. | 30 | 5 | 9 | 16 | 6.7 | 0.0 | 0.0 |
| Kansas City | 963 | 161 | 181 | 28.80 | 29.82 | -.10 | 68.3 | -5.3 | 88 | 21 | 77 | 50 | 3 | 60 | 25 | 61 | 57 | 72 | 5.43 | +0.4 | 17 | 5,930 | se. | 38 | sw. | 12 | 5 | 14 | 11 | 6.1 | 0.0 | 0.0 |
| St. Joseph | 967 | 11 | 49 | 28.79 | 29.81 | | 68.2 | | 88 | 21 | 77 | 52 | 2 | 59 | 27 | 60 | 56 | 70 | 10.77 | | 16 | 4,698 | se. | 36 | nw. | 17 | 6 | 13 | 11 | 5.8 | 0.0 | 0.0 |
| Springfield, Mo | 1,324 | 98 | 104 | 28.47 | 29.85 | -.10 | 66.8 | -5.7 | 87 | 18 | 74 | 49 | 6 | 60 | 23 | 63 | 60 | 79 | 12.27 | +7.1 | 17 | 6,544 | s. | 34 | se. | 28 | 11 | 12 | 7 | 5.0 | 0.0 | 0.0 |
| Iola | 984 | 11 | 50 | 28.78 | 29.80 | -.13 | 69.6 | -4.5 | 90 | 21 | 79 | 50 | 4 | 60 | 28 | | | | 10.58 | +5.1 | 16 | 3,803 | se. | 26 | nw. | 22 | 8 | 11 | 11 | 5.8 | 0.0 | 0.0 |
| Topeka | 987 | 92 | 107 | | | | 68.8 | -4.6 | 91 | 21 | 78 | 51 | 4 | 60 | 30 | | | | 5.11 | +0.3 | 15 | 5,489 | n. | 34 | s. | 16 | 8 | 16 | 6 | 5.5 | 0.0 | 0.0 |
| Lincoln | 1,189 | 11 | 81 | 28.57 | 29.80 | -.10 | 66.8 | -4.6 | 88 | 20 | 76 | 48 | 2 | 57 | 27 | 59 | 53 | 67 | 3.97 | -0.4 | 17 | 5,500 | s. | 33 | nw. | 22 | 2 | 16 | 12 | 6.6 | 0.0 | 0.0 |
| Omaha | 1,105 | 115 | 122 | 28.66 | 29.82 | -.09 | 67.1 | -4.5 | 87 | 20 | 75 | 51 | 10 | 59 | 25 | 59 | 53 | 66 | 5.20 | +0.6 | 12 | 4,593 | n. | 26 | n. | 24 | 11 | 9 | 10 | 5.5 | 0.0 | 0.0 |
| Valentine | 2,598 | 47 | 54 | 27.17 | 29.85 | -.01 | 61.4 | -5.5 | 91 | 30 | 72 | 40 | 10 | 51 | 35 | 53 | 48 | 69 | 3.35 | -0.5 | 15 | 5,587 | w. | 38 | nw. | 12 | 5 | 12 | 13 | 6.2 | 0.0 | 0.0 |
| Sioux City | 1,135 | 94 | 164 | 28.64 | 29.83 | -.07 | 65.0 | -4.5 | 82 | 16 | 74 | 45 | 10 | 56 | 31 | 57 | 52 | 66 | 3.07 | -0.8 | 13 | 6,945 | nw. | 40 | sw. | 12 | 3 | 13 | 14 | 6.6 | 0.0 | 0.0 |
| Huron | 1,306 | 59 | 74 | 28.44 | 29.82 | -.06 | 63.0 | -3.2 | 87 | 7 | 75 | 40 | 10 | 52 | 37 | 55 | 48 | 65 | 6.50 | +2.7 | 13 | 5,590 | nw. | 32 | se. | 15 | 4 | 21 | 5 | 5.7 | 0.0 | 0.0 |
| Pierre | 1,572 | 70 | 75 | | 29.81 | -.06 | 63.8 | -4.7 | 93 | 30 | 76 | 46 | 10 | 52 | 33 | | | 64 | 2.18 | -0.9 | 9 | 5,365 | nw. | 46 | nw. | 12 | 5 | 19 | 6 | | 0.0 | 0.0 |
| Yankton | 1,233 | 49 | 57 | 28.53 | 29.82 | -.07 | 64.7 | -4.2 | 85 | 30 | 75 | 44 | 10 | 54 | 32 | | | | 3.50 | -0.3 | 12 | 4,443 | nw. | 30 | w. | 12 | 6 | 13 | 11 | 6.1 | 0.0 | 0.0 |

TABLE I.—*Climatological data for Weather Bureau stations, June, 1928*—Continued

| District and station | Elevation of instruments | | | Pressure | | | Temperature of the air | | | | | | | | | | | | Precipitation | | | Wind | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Barometer above sea level | Thermometer above ground | Anemometer above ground | Station reduced to mean of 24 hours | Sea level, reduced to mean of 24 hours | Departure from normal | Mean max. + mean min. ÷ 2 | Departure from normal | Maximum | Date | Mean maximum | Minimum | Date | Mean minimum | Greatest daily range | Mean wet thermometer | Mean temperature of the dew point | Mean relative humidity | Total | Departure from normal | Days with .01, or more | Total movement | Prevailing direction | Maximum velocity: Miles per hour | Maximum velocity: Direction | Maximum velocity: Date | Clear days | Partly cloudy days | Cloudy days | Average cloudiness, tenths | Total snowfall | Snow, sleet, and ice on ground at end of month |
| | Ft. | Ft. | Ft. | In. | In. | In. | °F. | °F. | °F. | | °F. | °F. | | °F. | °F. | °F. | °F. | % | In. | In. | | Miles | | | | | | | | 0-10 | In. | In. |
| ***Northern Slope*** | | | | | | | 56.9 | -4.5 | | | | | | | | | | 66 | 3.58 | +1.3 | | | | | | | | | | 6.2 | | |
| Billings | 3,140 | 5 | | | | | 59.2 | | 85 | 28 | 74 | 31 | 1 | 45 | 47 | | | | 1.67 | | 16 | | nw. | | | | 3 | 10 | 17 | | 0.0 | 0.0 |
| Havre | 2,505 | 11 | 44 | 27.22 | 29.83 | -0.02 | 58.8 | -3.2 | 84 | 28 | 70 | 34 | 9 | 48 | 36 | 51 | 44 | 66 | 4.32 | +1.5 | 13 | 4,455 | sw. | 33 | sw. | 14 | 4 | 13 | 13 | 6.7 | 0.0 | 0.0 |
| Helena | 4,110 | 87 | 112 | 25.72 | 29.86 | -.02 | 56.4 | -2.8 | 80 | 28 | 66 | 39 | 1 | 46 | 33 | 47 | 39 | 58 | 2.98 | +0.9 | 17 | 5,696 | sw. | 33 | sw. | 28 | 3 | 14 | 13 | 6.9 | 0.0 | 0.0 |
| Kalispell | 2,973 | 48 | 56 | 26.83 | 29.85 | -.04 | 56.6 | -1.1 | 82 | 26 | 66 | 38 | 9 | 47 | 30 | 49 | 43 | 67 | 2.51 | +0.8 | 15 | 3,720 | nw. | 38 | sw. | 6 | 6 | 16 | 8 | 5.9 | 0.0 | 0.0 |
| Miles City | 2,371 | 48 | 55 | 27.33 | 29.85 | .00 | 60.7 | -5.3 | 83 | 30 | 72 | 39 | 1 | 50 | 34 | 51 | 44 | 61 | 2.83 | +0.1 | 13 | 3,889 | s. | 37 | w. | 6 | 7 | 15 | 8 | 5.7 | 0.0 | 0.0 |
| Rapid City | 3,259 | 50 | 58 | 26.50 | 29.87 | +.02 | 58.0 | -6.2 | 82 | 30 | 68 | 41 | 13 | 48 | 34 | 51 | 46 | 69 | 6.15 | +2.6 | 19 | 4,676 | n. | 30 | nw. | 12 | 4 | 13 | 13 | 6.7 | 0.0 | 0.0 |
| Cheyenne | 6,088 | 84 | 101 | 23.93 | 29.81 | -.03 | 54.4 | -6.0 | 79 | 30 | 65 | 38 | 13 | 44 | 32 | 47 | 42 | 69 | 2.85 | +1.2 | 20 | 6,696 | s. | 33 | nw. | 12 | 5 | 14 | 11 | 6.3 | 0.0 | 0.0 |
| Lander | 5,372 | 60 | 68 | 24.55 | 29.82 | -.03 | 55.6 | -4.9 | 85 | 30 | 68 | 36 | 19 | 43 | 43 | 48 | 42 | 63 | 2.96 | +1.8 | 13 | 3,541 | w. | 31 | sw. | 29 | 10 | 15 | 5 | 4.6 | 0.0 | 0.0 |
| Sheridan | 3,790 | 10 | 47 | 25.99 | 29.84 | | 56.5 | | 82 | 6 | 69 | 32 | 1 | 44 | 43 | 50 | 43 | 66 | 3.23 | | 17 | 2,796 | nw. | 21 | nw. | 6 | 8 | 16 | 6 | 5.8 | 0.0 | 0.0 |
| Yellowstone Park | 6,241 | 11 | 48 | 23.82 | 29.86 | .00 | 49.6 | -6.4 | 73 | 28 | 61 | 31 | 1 | 38 | 35 | 41 | 35 | 65 | 2.99 | +1.4 | 18 | 4,585 | n. | 34 | sw. | 6 | 0 | 14 | 16 | 7.4 | 7.1 | 0.0 |
| North Platte | 2,821 | 11 | 51 | 26.95 | 29.83 | -.03 | 62.2 | -4.7 | 85 | 30 | 72 | 44 | 13 | 52 | 34 | 55 | 51 | 72 | 4.64 | +1.4 | 19 | 4,034 | se. | 26 | w. | 12 | 7 | 11 | 12 | 6.1 | 0.0 | 0.0 |
| ***Middle Slope*** | | | | | | | 67.4 | -4.5 | | | | | | | | | | 69 | 5.05 | +2.0 | | | | | | | | | | 5.7 | | |
| Denver | 5,292 | 106 | 113 | 24.64 | 29.80 | -.04 | 61.0 | -5.3 | 89 | 27 | 72 | 42 | 3 | 50 | 37 | 51 | 43 | 59 | 2.42 | +1.0 | 11 | 4,802 | n. | 27 | w. | 11 | 9 | 12 | 9 | 5.5 | 0.0 | 0.0 |
| Pueblo | 4,685 | 80 | 86 | 25.18 | 29.75 | -.08 | 65.6 | -3.4 | 92 | 7 | 78 | 44 | 4 | 53 | 39 | 54 | 45 | 58 | 1.47 | 0.0 | 9 | 4,729 | e. | 32 | w. | 11 | 14 | 13 | 3 | 4.1 | 0.0 | 0.0 |
| Concordia | 1,392 | 50 | 58 | 28.40 | 29.84 | -.06 | 67.0 | -6.0 | 87 | 21 | 76 | 50 | 4 | 58 | 27 | 61 | 58 | 75 | 4.79 | +0.4 | 18 | 4,511 | s. | 30 | w. | 23 | 4 | 12 | 14 | 6.5 | 0.0 | 0.0 |
| Dodge City | 2,509 | 11 | 51 | 27.27 | 29.83 | -.04 | 66.5 | -6.0 | 90 | 16 | 77 | 40 | 5 | 56 | 32 | 60 | 56 | 75 | 5.30 | +2.0 | 21 | 5,893 | se. | 44 | n. | 8 | 13 | 9 | 8 | 4.6 | 0.0 | 0.0 |
| Wichita | 1,358 | 139 | 158 | 28.39 | 29.79 | -.12 | 69.3 | -5.1 | 89 | 18 | 79 | 49 | 4 | 60 | 28 | 63 | 59 | 74 | 12.10 | +7.4 | 18 | 7,076 | s. | 44 | ne. | 8 | 6 | 16 | 8 | 5.8 | 0.0 | 0.0 |
| Broken Arrow | 765 | 11 | 56 | 29.00 | 29.81 | | 72.2 | | 87 | 18 | 80 | 54 | 6 | 65 | 26 | | | | 5.77 | | 15 | 8,628 | s. | 52 | nw. | 9 | 3 | 8 | 19 | 7.5 | 0.0 | 0.0 |
| Oklahoma City | 1,214 | 10 | 47 | 28.53 | 29.77 | -.14 | 74.8 | -1.2 | 96 | 17 | 84 | 52 | 5 | 66 | 27 | 67 | 64 | 74 | 4.21 | +1.1 | 12 | 6,759 | s. | 26 | se. | 12 | 7 | 15 | 8 | 5.6 | 0.0 | 0.0 |
| ***Southern Slope*** | | | | | | | 79.0 | +1.0 | | | | | | | | | | 52 | 2.05 | -0.5 | | | | | | | | | | 2.9 | | |
| Abilene | 1,738 | 10 | 52 | 27.98 | 29.73 | -.15 | 81.3 | +2.1 | 105 | 28 | 93 | 51 | 5 | 70 | 30 | 68 | 61 | 58 | 2.52 | -0.5 | 9 | 8,474 | s. | 33 | s. | 17 | 18 | 10 | 2 | 3.2 | 0.0 | 0.0 |
| Amarillo | 3,676 | 10 | 49 | 26.12 | 29.74 | -.11 | 72.1 | -0.7 | 99 | 16 | 85 | 46 | 4 | 59 | 36 | 60 | 52 | 58 | 3.45 | +0.5 | 5 | 6,614 | e. | 24 | s. | 7 | 17 | 7 | 6 | 3.5 | 0.0 | 0.0 |
| Del Rio | 944 | 64 | 71 | 28.76 | 29.71 | -.14 | 85.0 | +1.6 | 105 | 23 | 95 | 64 | 5 | 75 | 28 | 71 | 64 | 57 | 0.71 | -1.7 | 3 | 7,958 | se. | 27 | se. | 8 | 16 | 13 | 1 | 3.4 | 0.0 | 0.0 |
| Roswell | 3,566 | 75 | 85 | 26.19 | 29.69 | -.11 | 77.5 | +1.2 | 104 | 27 | 92 | 48 | 5 | 62 | 39 | 57 | 39 | 34 | 1.53 | -0.2 | 2 | 6,055 | s. | 29 | s. | 11 | 23 | 7 | 0 | 1.5 | 0.0 | 0.0 |
| ***Southern Plateau*** | | | | | | | 74.8 | +0.6 | | | | | | | | | | 29 | 0.03 | -0.4 | | | | | | | | | | 1.0 | | |
| El Paso | 3,778 | 152 | 175 | 26.03 | 29.68 | -.07 | 82.6 | +3.0 | 103 | 23 | 95 | 58 | 13 | 70 | 38 | 56 | 31 | 19 | T. | -0.6 | 0 | 8,816 | w. | 44 | w. | 11 | 26 | 4 | 0 | 1.4 | 0.0 | 0.0 |
| Santa Fe | 7,013 | 38 | 53 | 23.19 | 29.66 | -.15 | 64.6 | -0.2 | 88 | 27 | 79 | 39 | 13 | 50 | 37 | 47 | 28 | 29 | 0.11 | -1.0 | 1 | 4,610 | sw. | 32 | sw. | 11 | 23 | 6 | 1 | 2.1 | 0.0 | 0.0 |
| Flagstaff | 6,907 | 10 | 59 | 23.32 | 29.72 | -.06 | 58.9 | -0.4 | 89 | 24 | 75 | 32 | 13 | 43 | 45 | 43 | 27 | 38 | 0.05 | | 1 | | sw. | | sw. | | 26 | 4 | 0 | | 0.0 | 0.0 |
| Phoenix | 1,108 | 10 | 82 | 28.55 | 29.67 | -.07 | 85.6 | +1.1 | 110 | 24 | 101 | 61 | 12 | 70 | 39 | 60 | 38 | 23 | 0.00 | -0.1 | 0 | 3,697 | w. | 21 | n. | 3 | 29 | 1 | 0 | 0.3 | 0.0 | 0.0 |
| Yuma | 141 | 9 | 54 | 29.53 | 29.67 | -.07 | 85.3 | +0.6 | 114 | 6 | 102 | 61 | 12 | 68 | 43 | 64 | 47 | 35 | 0.00 | 0.0 | 0 | 3,407 | sw. | 22 | w. | 10 | 30 | 0 | 0 | 0.1 | 0.0 | 0.0 |
| Independence | 3,957 | 5 | 25 | 25.80 | 29.74 | -.04 | 71.8 | -0.5 | 98 | 24 | 88 | 45 | 11 | 56 | 37 | 51 | | | T. | | 0 | | nw. | | | | 27 | 1 | 2 | 1.2 | 0.0 | 0.0 |
| ***Middle Plateau*** | | | | | | | 64.8 | -0.4 | | | | | | | | | | 34 | 0.41 | -0.1 | | | | | | | | | | 2.3 | | |
| Reno | 4,532 | 74 | 81 | 25.39 | 29.80 | -.06 | 63.3 | +2.3 | 94 | 23 | 79 | 40 | 10 | 48 | 40 | 48 | 36 | 41 | 0.11 | -0.2 | 2 | 5,604 | w. | 34 | w. | 27 | 26 | 2 | 2 | 1.7 | 0.0 | 0.0 |
| Tonopah | 6,090 | 12 | 20 | | | | 65.4 | | 91 | 24 | 78 | 32 | 11 | 53 | 34 | 46 | 25 | 25 | 0.08 | | 1 | | nw. | | | | | | | | | |
| Winnemucca | 4,344 | 18 | 56 | 25.53 | 29.85 | -.03 | 62.5 | -0.3 | 97 | 24 | 79 | 34 | 18 | 46 | 43 | 47 | 33 | 43 | 0.43 | -0.3 | 4 | 4,234 | sw. | 24 | nw. | 2 | 24 | 6 | 0 | 2.3 | 0.0 | 0.0 |
| Modena | 5,473 | 10 | 43 | 24.50 | 29.72 | -.10 | 63.4 | +0.1 | 93 | 24 | 80 | 35 | 19 | 46 | 45 | 45 | 27 | 31 | 0.26 | -0.1 | 2 | 8,166 | sw. | 48 | sw. | 10 | 24 | 3 | 3 | 1.8 | 0.0 | 0.0 |
| Salt Lake City | 4,360 | 163 | 203 | 25.48 | 29.77 | -.08 | 65.4 | -2.0 | 94 | 25 | 77 | 40 | 18 | 54 | 33 | 49 | 34 | 35 | 0.41 | -0.4 | 4 | 4,941 | nw. | 30 | se. | 10 | 15 | 11 | 4 | 3.4 | 0.0 | 0.0 |
| Grand Junction | 4,602 | 60 | 68 | 25.22 | 29.72 | -.11 | 69.2 | -2.2 | 97 | 26 | 84 | 43 | 12 | 55 | 34 | 49 | 30 | 31 | 0.84 | +0.4 | 5 | 4,631 | se. | 30 | s. | 11 | 19 | 9 | 2 | 2.5 | 0.0 | 0.0 |
| ***Northern Plateau*** | | | | | | | 63.0 | -0.7 | | | | | | | | | | 51 | 0.82 | -0.3 | | | | | | | | | | 5.3 | | |
| Baker | 3,471 | 48 | 53 | 26.38 | 29.93 | -.02 | 56.4 | -2.2 | 91 | 24 | 70 | 32 | 7 | 43 | 39 | 46 | 38 | 58 | 1.46 | +0.2 | 9 | 3,838 | se. | 26 | n. | 20 | 11 | 7 | 12 | 5.6 | 0.0 | 0.0 |
| Boise | 2,739 | 78 | 86 | 27.04 | 29.86 | -.05 | 63.6 | -1.7 | 98 | 24 | 77 | 39 | 7 | 51 | 39 | 52 | 42 | 52 | 0.44 | -0.5 | 7 | 4,036 | w. | 24 | n. | 11 | 12 | 11 | 7 | 4.4 | 0.0 | 0.0 |
| Lewiston | 757 | 40 | 48 | 29.07 | 29.87 | -.07 | 67.0 | +0.4 | 102 | 24 | 80 | 43 | 7 | 54 | 40 | | | | 1.03 | 0.0 | 11 | 2,603 | e. | 28 | nw. | 6 | 5 | 14 | 11 | 6.0 | 0.0 | 0.0 |
| Pocatello | 4,477 | 60 | 68 | 25.36 | 29.80 | -.07 | 60.0 | -2.2 | 89 | 25 | 73 | 40 | 18 | 47 | 37 | 47 | 36 | 49 | 1.00 | 0.0 | 10 | 5,078 | sw. | 28 | sw. | 14 | 9 | 13 | 8 | 5.4 | 0.0 | 0.0 |
| Spokane | 1,929 | 101 | 110 | 27.85 | 29.87 | -.07 | 63.6 | +0.8 | 94 | 24 | 75 | 42 | 7 | 52 | 34 | 51 | 40 | 48 | 0.43 | -0.8 | 8 | 4,611 | s. | 28 | sw. | 6 | 5 | 18 | 7 | 5.9 | 0.0 | 0.0 |
| Walla Walla | 991 | 57 | 65 | 28.82 | 29.88 | -.08 | 67.2 | +0.7 | 99 | 24 | 78 | 47 | 7 | 56 | 35 | 54 | 43 | 46 | 0.58 | -0.5 | 6 | 3,400 | s. | 19 | sw. | 6 | 14 | 9 | 7 | 4.6 | 0.0 | 0.0 |
| ***North Pacific Coast Region*** | | | | | | | 58.9 | +0.5 | | | | | | | | | | 71 | 0.81 | -1.1 | | | | | | | | | | 6.8 | | |
| North Head | 211 | 11 | 56 | 29.78 | 30.00 | +.01 | 56.0 | +1.2 | 63 | 29 | 59 | 49 | 7 | 53 | 10 | 53 | 51 | 85 | 1.42 | -0.5 | 15 | 7,793 | n. | 32 | n. | 6 | 0 | 3 | 27 | 9.2 | 0.0 | 0.0 |
| Port Angeles | 29 | 8 | 53 | | 30.03 | | 56.2 | | 78 | 20 | 63 | 40 | 7 | 49 | 26 | | | | 0.50 | -0.8 | 5 | 4,701 | nw. | 27 | w. | 6 | 6 | 7 | 17 | | 0.0 | 0.0 |
| Seattle | 125 | 215 | 250 | 29.86 | 29.99 | -.01 | 59.5 | +0.5 | 81 | 23 | 67 | 48 | 7 | 52 | 30 | 53 | 49 | 71 | 1.32 | -0.1 | 9 | 4,156 | nw. | 22 | sw. | 1 | 3 | 8 | 19 | 7.6 | 0.0 | 0.0 |
| Tacoma | 194 | 172 | 201 | 29.81 | 30.01 | -.02 | 59.9 | +1.2 | 83 | 20 | 68 | 44 | 7 | 52 | 27 | | | | 0.48 | -1.2 | 8 | 4,885 | sw. | 29 | sw. | 6 | 2 | 13 | 15 | 7.0 | 0.0 | 0.0 |
| Tatoosh Island | 86 | 9 | 53 | 29.92 | 30.02 | .00 | 54.2 | +1.2 | 62 | 29 | 57 | 49 | 6 | 51 | 9 | 52 | 51 | 91 | 0.84 | -3.3 | 12 | 6,055 | w. | 31 | s. | 20 | 0 | 11 | 19 | 8.0 | 0.0 | 0.0 |
| Yakima | 1,071 | 5 | | | | | 66.4 | | 100 | 24 | 81 | 36 | 7 | 52 | 38 | 54 | | 55 | 0.20 | | 4 | | nw. | | | | 9 | 14 | 7 | 5.1 | 0.0 | 0.0 |
| Medford | 1,425 | 4 | 80 | 28.45 | 29.93 | | 63.4 | | 92 | 23 | 78 | 42 | 18 | 48 | 43 | 53 | 47 | 62 | 0.82 | | 3 | | nw. | 18 | nw. | 2 | 13 | 8 | 9 | 4.4 | 0.0 | 0.0 |
| Portland, Oreg | 153 | 68 | 106 | 29.85 | 30.01 | -.03 | 62.2 | -0.2 | 86 | 23 | 70 | 48 | 8 | 55 | 27 | 55 | 50 | 67 | 0.44 | -1.1 | 9 | 3,289 | nw. | 16 | nw. | 6 | 4 | 5 | 21 | 7.9 | 0.0 | 0.0 |
| Roseburg | 510 | 75 | 99 | 29.46 | 30.00 | -.03 | 61.6 | -0.9 | 86 | 22 | 72 | 44 | 18 | 52 | 36 | 53 | 47 | 64 | 0.70 | -0.4 | 3 | 3,027 | n. | 17 | n. | 17 | 11 | 7 | 12 | 5.6 | 0.0 | 0.0 |
| ***Middle Pacific Coast Region*** | | | | | | | 65.7 | +1.3 | | | | | | | | | | 63 | 0.10 | -0.2 | | | | | | | | | | 2.3 | | |
| Eureka | 62 | 73 | 89 | 29.98 | 30.05 | .00 | 55.3 | +1.0 | 64 | 29 | 60 | 46 | 7 | 51 | 14 | 52 | 50 | 84 | 0.32 | -0.4 | 3 | 4,895 | n. | 27 | nw. | 18 | 7 | 8 | 15 | 6.5 | 0.0 | 0.0 |
| Red Bluff | 330 | 54 | 58 | 29.47 | 29.82 | -.06 | 76.0 | +1.2 | 105 | 5 | 90 | 49 | 11 | 62 | 38 | 58 | 43 | 36 | 0.13 | -0.3 | 2 | 4,622 | nw. | 22 | nw. | 17 | 26 | 4 | 0 | 1.2 | 0.0 | 0.0 |
| Sacramento | 69 | 106 | 117 | 29.75 | 29.82 | -.07 | 71.7 | +2.3 | 103 | 5 | 87 | 50 | 11 | 57 | 38 | 59 | 51 | 57 | 0.04 | -0.1 | 1 | 5,944 | s. | 23 | nw. | 3 | 29 | 1 | 0 | 0.6 | 0.0 | 0.0 |
| San Francisco | 155 | 208 | 243 | 29.73 | 29.90 | -.06 | 60.6 | +2.1 | 85 | 6 | 68 | 50 | 16 | 53 | 34 | 54 | 50 | 75 | T. | -0.2 | 0 | 6,863 | w. | 33 | w. | 9 | 26 | 4 | 0 | 1.7 | 0.0 | 0.0 |
| San Jose | 141 | 12 | 110 | 29.76 | 29.91 | | 64.7 | -0.3 | 97 | 6 | 78 | 46 | 15 | 51 | 44 | | | | 0.01 | -0.1 | 1 | 4,416 | nw. | 25 | sw. | 19 | 26 | 4 | 0 | 1.4 | 0.0 | 0.0 |
| ***South Pacific Coast Region*** | | | | | | | 68.3 | -0.4 | | | | | | | | | | 65 | 0.03 | -0.1 | | | | | | | | | | 3.3 | | |
| Fresno | 327 | 89 | 98 | 29.47 | 29.81 | -.04 | 75.6 | -0.2 | 105 | 6 | 91 | 50 | 11 | 60 | 40 | 57 | 41 | 37 | 0.00 | -0.1 | 0 | 6,559 | nw. | 27 | nw. | 10 | 30 | 0 | 0 | 0.4 | 0.0 | 0.0 |
| Los Angeles | 338 | 159 | 191 | 29.51 | 29.87 | -.03 | 65.4 | -1.0 | 80 | 16 | 73 | 54 | 11 | 58 | 21 | 59 | 55 | 75 | 0.01 | -0.1 | 1 | 3,436 | sw. | 15 | w. | 10 | 15 | 9 | 6 | 4.2 | 0.0 | 0.0 |
| San Diego | 87 | 62 | 70 | 29.78 | 29.87 | -.05 | 64.0 | +0.1 | 74 | 16 | 68 | 56 | 12 | 60 | 13 | 60 | 58 | 83 | 0.09 | 0.0 | 2 | 4,449 | w. | 17 | w. | 21 | 12 | 8 | 10 | 5.4 | 0.0 | 0.0 |
| ***West Indies*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| San Juan, P. R. | 82 | 9 | 54 | 29.91 | 29.99 | | 79.8 | +0.1 | 91 | 9 | 85 | 72 | 28 | 75 | 17 | | | | 2.58 | -3.3 | 12 | 9,066 | e. | 30 | e. | 23 | 5 | 18 | 7 | 5.7 | 0.0 | 0.0 |
| ***Panama Canal*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Balboa Heights | 118 | 7 | 97 | [1] 29.71 | [1] 29.81 | -0.1 | 79.4 | -0.7 | 90 | 18 | 85 | 72 | 26 | 74 | 14 | | | | 8.78 | +0.7 | 24 | | nw. | | nw. | 19 | 0 | 4 | 26 | 8.7 | 0.0 | 0.0 |
| Colon | 38 | 7 | 97 | [1] 29.79 | [1] 29.81 | -0.2 | 80.2 | -0.2 | 90 | 20 | 86 | 73 | 16 | 75 | 15 | | | | 16.22 | +2.5 | 23 | | se. | | nw. | 16 | 0 | 2 | 28 | 9.1 | 0.0 | 0.0 |
| ***Alaska*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Juneau | 80 | 11 | 54 | [2] 29.94 | [2] 30.03 | | 55.7 | | 78 | 10 | 65 | 40 | 1 | 46 | 33 | 50 | 44 | 68 | 0.93 | | 9 | 4,347 | nw. | 23 | nw. | 24 | 11 | 10 | 9 | 5.4 | 0.0 | 0.0 |
| ***Hawaiian Islands*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Honolulu | 38 | 86 | 100 | [2] 29.97 | [2] 30.01 | | 76.5 | | 84 | 2 | 81 | 68 | 1 | 72 | 15 | 68 | 64 | 67 | 0.29 | -0.6 | 9 | 5,958 | e. | 22 | e. | 18 | 7 | 22 | 1 | 4.9 | 0.0 | 0.0 |

[1] Observations taken bihourly.

[2] Pressure not corrected to mean of 24 hours.

**TABLE 2.**—*Data furnished by the Canadian Meterological Service, June, 1928*

| Station | Altitude above mean sea level Jan. 1, 1919 | Pressure | | | Temperature of the air | | | | | | Precipitation | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Station reduced to mean of 24 hours | Sea level reduced to mean of 24 hours | Departure from normal | Mean max. + mean min. ÷ 2 | Departure from normal | Mean maximum | Mean minimum | Highest | Lowest | Total | Departure from normal | Total snowfall |
| | *Feet* | *Inches* | *Inches* | *Inches* | °*F.* | °*F.* | °*F.* | °*F.* | °*F.* | °*F.* | *Inches* | *Inches* | *Inches* |
| Cape Race, N. F | 99 | | | | | | | | | | | | |
| Sydney, C. B. I | 48 | 29.87 | 29.92 | −0.06 | 56.7 | +1.3 | 66.0 | 47.3 | 81 | 40 | 2.50 | −0.73 | 0.0 |
| Halifax, N. S | 88 | 29.84 | 29.94 | .00 | 56.9 | −0.8 | 66.0 | 47.8 | 78 | 42 | 2.75 | −1.01 | 0.0 |
| Yarmouth, N. S | 65 | 29.79 | 29.86 | −.09 | 54.2 | −0.8 | 59.9 | 48.6 | 67 | 41 | 3.12 | +0.19 | 0.0 |
| Charlottetown, P. E. I | 38 | 29.80 | 29.84 | −.08 | 58.4 | +1.0 | 65.2 | 51.5 | 79 | 44 | 2.46 | −0.21 | 0.0 |
| Chatham, N. B | 28 | 29.77 | 29.80 | −.09 | 57.1 | −2.9 | 67.9 | 46.4 | 82 | 34 | 3.29 | −0.17 | 0.0 |
| Father Point, Que | 20 | | | | | | | | | | | | |
| Quebec, Que | 296 | 29.55 | 29.86 | −.06 | 60.5 | −0.7 | 69.1 | 51.9 | 78 | 44 | 5.22 | +1.57 | 0.0 |
| Doucet, Que | 1,236 | | | | 55.4 | | 70.4 | 40.5 | 83 | 21 | 3.48 | | 0.0 |
| Montreal, Que | 187 | 29.63 | 29.83 | −.11 | 63.9 | −1.0 | 72.5 | 55.3 | 85 | 48 | 3.15 | −0.38 | 0.0 |
| Ottawa, Ont | 236 | 29.58 | 29.84 | −.10 | 62.4 | −2.9 | 72.4 | 52.3 | 84 | 41 | 5.17 | +2.25 | 0.0 |
| Kingston, Ont | 285 | | | | | | | | | | | | |
| Toronto, Ont | 379 | 29.45 | 29.85 | −.12 | 61.5 | −1.9 | 70.5 | 52.5 | 81 | 38 | 3.97 | +1.17 | 0.0 |
| Cochrane, Ont | 930 | | | | 54.0 | | 65.1 | 42.9 | 81 | 31 | 2.86 | | 0.0 |
| White River, Ont | 1,244 | 28.52 | 29.82 | −.12 | 52.9 | −5.8 | 65.8 | 40.0 | 81 | 29 | 6.67 | +4.45 | 0.0 |
| London, Ont | 808 | | | | | | | | | | | | |
| Southampton, Ont | 656 | | | | | | | | | | | | |
| Parry Sound, Ont | 688 | 29.15 | 29.82 | −.14 | 60.7 | −1.0 | 71.1 | 50.4 | 83 | 37 | 3.80 | +1.38 | 0.0 |
| Port Arthur, Ont | 644 | 29.15 | 29.86 | −.08 | 54.4 | −2.0 | 62.0 | 46.8 | 81 | 35 | 4.91 | +2.18 | 0.0 |
| Winnipeg, Man | 760 | | | | | | | | | | | | |
| Minnedosa, Man | 1,690 | 28.06 | 29.85 | −.04 | 56.8 | −2.8 | 67.0 | 46.5 | 81 | 30 | 4.24 | +4.24 | 0.0 |
| Le Pas, Man | 860 | | | | 56.3 | | 68.8 | 43.9 | 82 | 32 | 1.51 | | 0.0 |
| Qu'Appelle, Sask | 2,115 | 27.63 | 29.85 | −.02 | 56.6 | −3.3 | 66.8 | 46.4 | 78 | 37 | 4.68 | +1.26 | 0.0 |
| Moose Jaw, Sask | 1,759 | | | | 57.4 | | 68.2 | 46.7 | 82 | 37 | 6.07 | | 0.0 |
| Swift Current, Sask | 2,392 | 27.29 | 29.78 | −.09 | 57.7 | −2.3 | 69.7 | 45.8 | 83 | 32 | 4.80 | +2.13 | 0.0 |
| Medicine Hat, Alb | 2,144 | | | | | | | | | | | | |
| Calgary, Alb | 3,428 | | | | | | | | | | | | |
| Banff, Alb | 4,521 | | | | | | | | | | | | |
| Prince Albert, Sask | 1,450 | 28.34 | 29.90 | +.03 | 57.9 | +0.2 | 68.9 | 46.9 | 86 | 35 | 1.65 | −0.86 | 0.0 |
| Battleford, Sask | 1,592 | 28.14 | 29.86 | .00 | 57.3 | −2.2 | 69.2 | 45.5 | 86 | 36 | 4.00 | +0.78 | 0.0 |
| Edmonton, Alb | 2,150 | | | | | | | | | | | | |
| Kamloops, B. C | 1,262 | | | | | | | | | | | | |
| Victoria, B. C | 230 | 29.73 | 29.98 | −.03 | 56.6 | +0.3 | 63.0 | 50.3 | 77 | 48 | 0.51 | −1.09 | 0.0 |
| Barkerville, B. C | 4,180 | | | | | | | | | | | | |
| Estevan Point, B. C | 20 | | | | | | | | | | | | |
| Prince Rupert, B. C | 170 | | | | | | | | | | | | |
| Hamilton, Ber | 151 | | | | | | | | | | | | |

## LATE REPORTS, MAY, 1928

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Father Point, Que | 20 | 29.89 | 29.91 | −0.02 | 45.0 | +1.0 | 52.0 | 38.1 | 67 | 32 | 2.82 | +0.24 | 0.0 |
| Medicine Hat, Alb | 2,144 | 27.63 | 29.86 | −.03 | 61.4 | +7.3 | 78.0 | 44.8 | 98 | 30 | 0.04 | −1.27 | 0.0 |
| Banff, Alb | 4,521 | 25.41 | 29.95 | +.11 | 49.5 | +2.5 | 64.7 | 34.3 | 83 | 24 | 0.66 | −1.38 | 0.0 |
| Edmonton, Alb | 2,150 | 27.60 | 29.86 | −.01 | 55.8 | +5.0 | 69.9 | 41.7 | 89 | 25 | 2.14 | +0.59 | 7.2 |
| Kamloops, B. C | 1,262 | 28.68 | 29.96 | +.07 | 61.1 | +2.0 | 73.2 | 49.0 | 89 | 35 | 0.29 | −0.95 | 0.0 |
| Barkerville, B. C | 4,180 | 25.68 | 29.98 | +.14 | 45.4 | −0.1 | 57.5 | 33.3 | 76 | 16 | 3.25 | +0.73 | 9.0 |
| Estevan Point, B. C | 20 | | | | 50.9 | | 56.6 | 45.1 | 65 | 38 | 10.69 | | 0.0 |
| Prince Rupert, B. C | 170 | | | | 49.7 | | 56.4 | 43.0 | 68 | 35 | 8.62 | | 0.0 |

**Chart I. Departure (°F.) of the Mean Temperature from the Normal, June, 1928**

## Chart I. Departure (°F.) of the Mean Temperature from the Normal, June, 1928


Shaded portions show excess (+).
Unshaded portions show deficiency (−).
Lines show amount of excess or deficiency.

## Chart II. Tracks of Centers of Anticyclones, June, 1928. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by Wilfred P. Day)

Chart III. Tracks of Centers of Cyclones, June, 1928. (Inset) Change in Mean Pressure from Preceding Month
(Plotted by Wilfred P. Day)

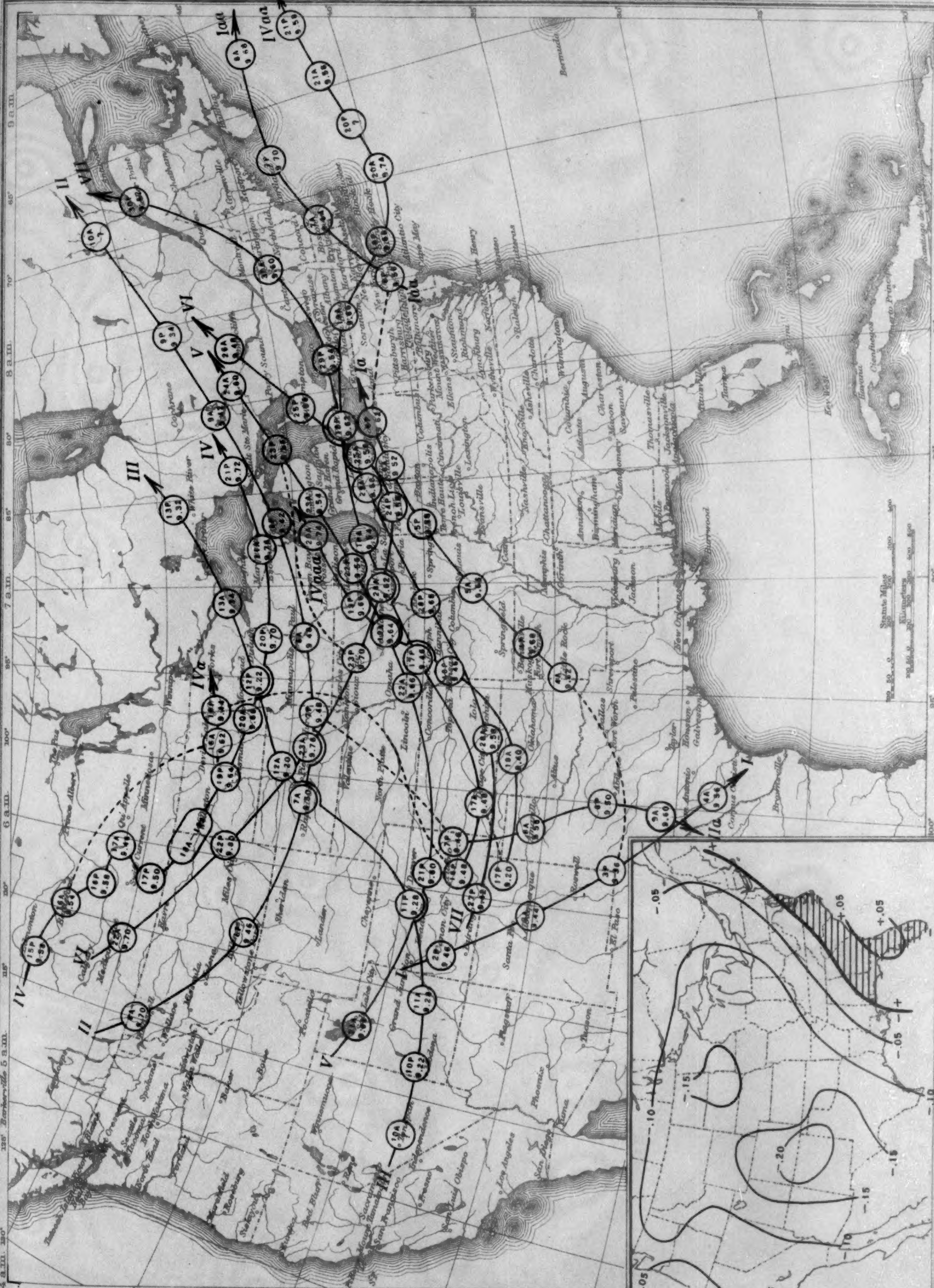


Chart IV. Percentage of Clear Sky between Sunrise and Sunset, June, 1928

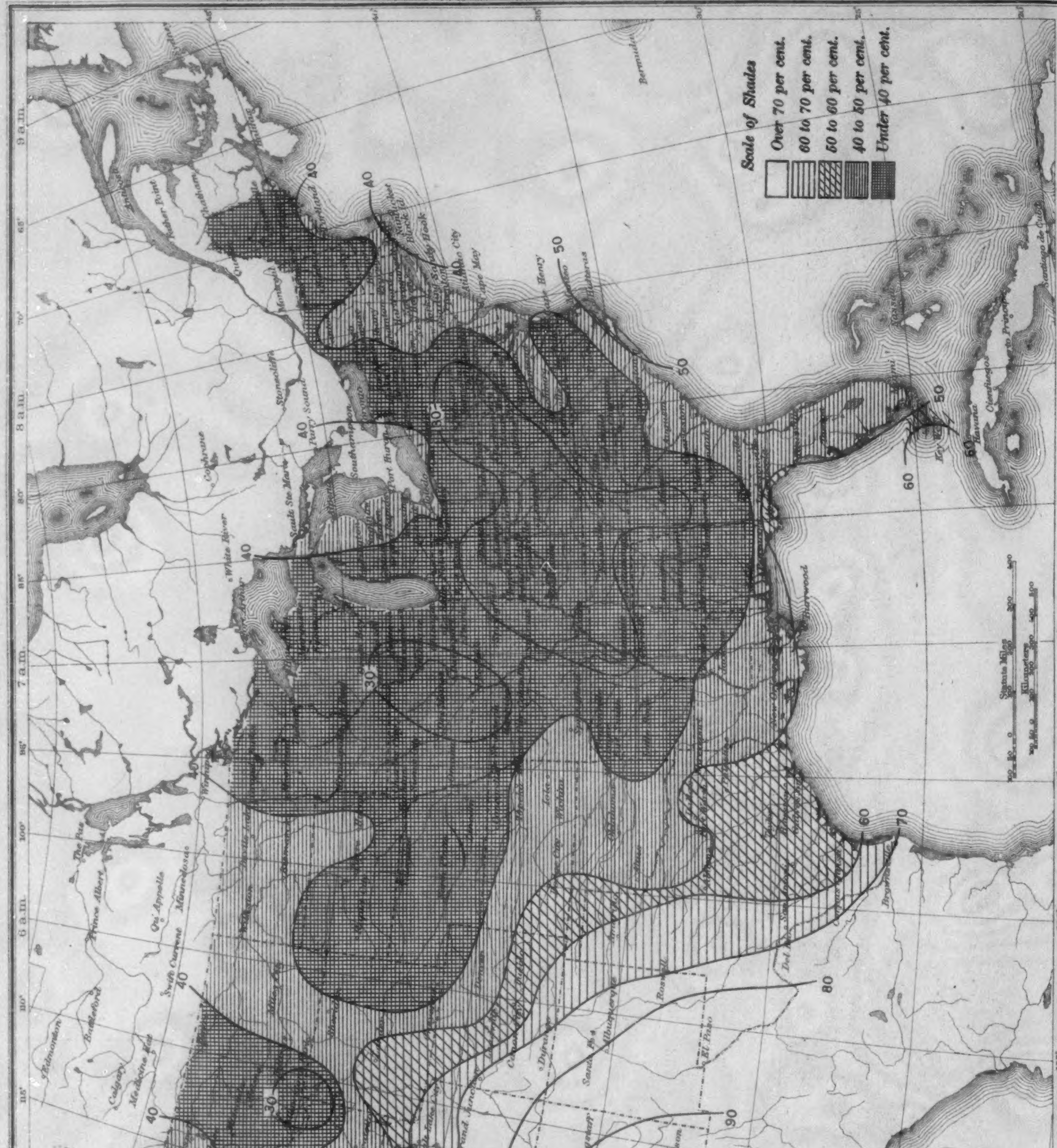


Chart V. Total Precipitation, Inches, June, 1928. (Inset) Departure of Precipitation from Normal

Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, June, 1928

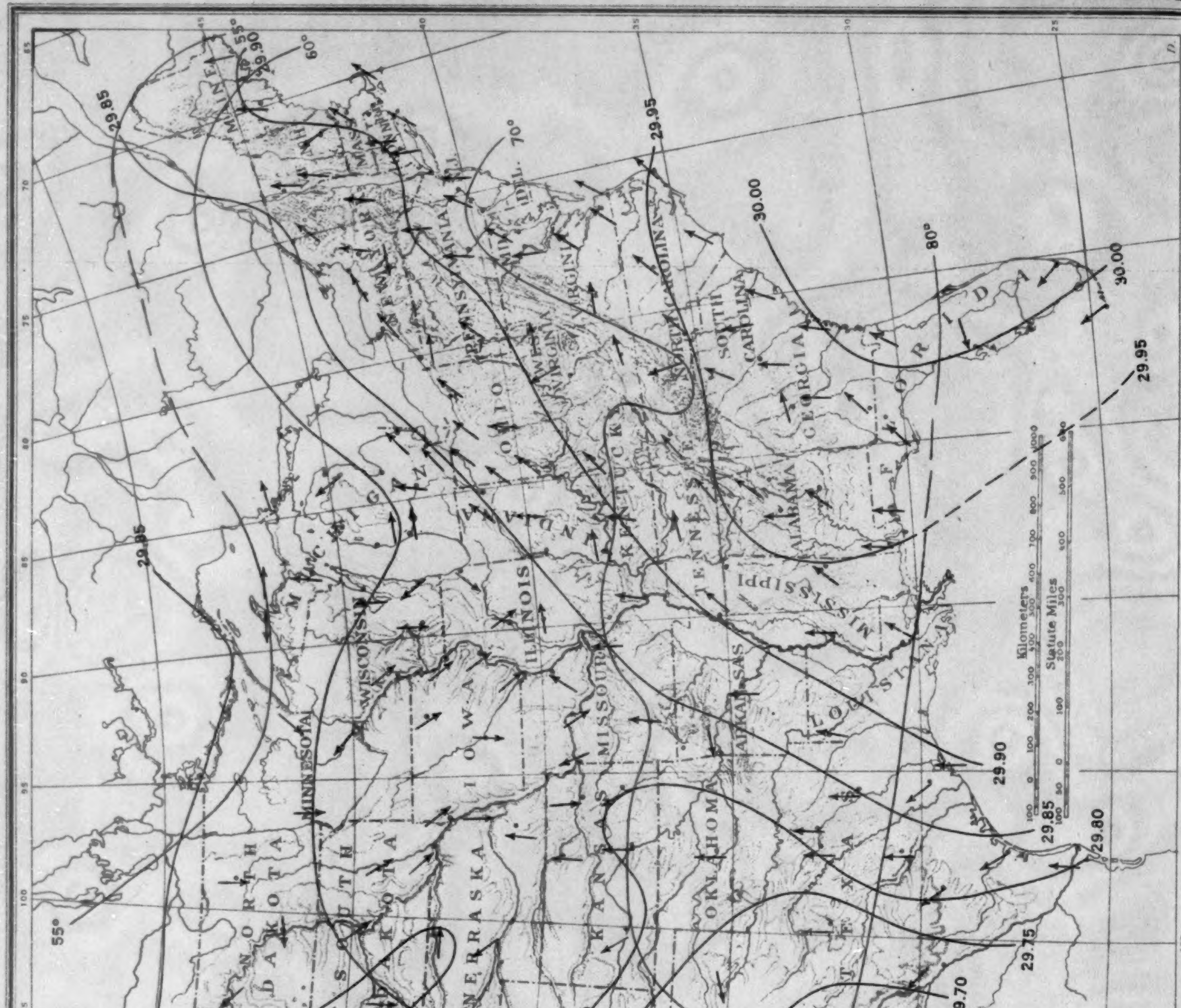
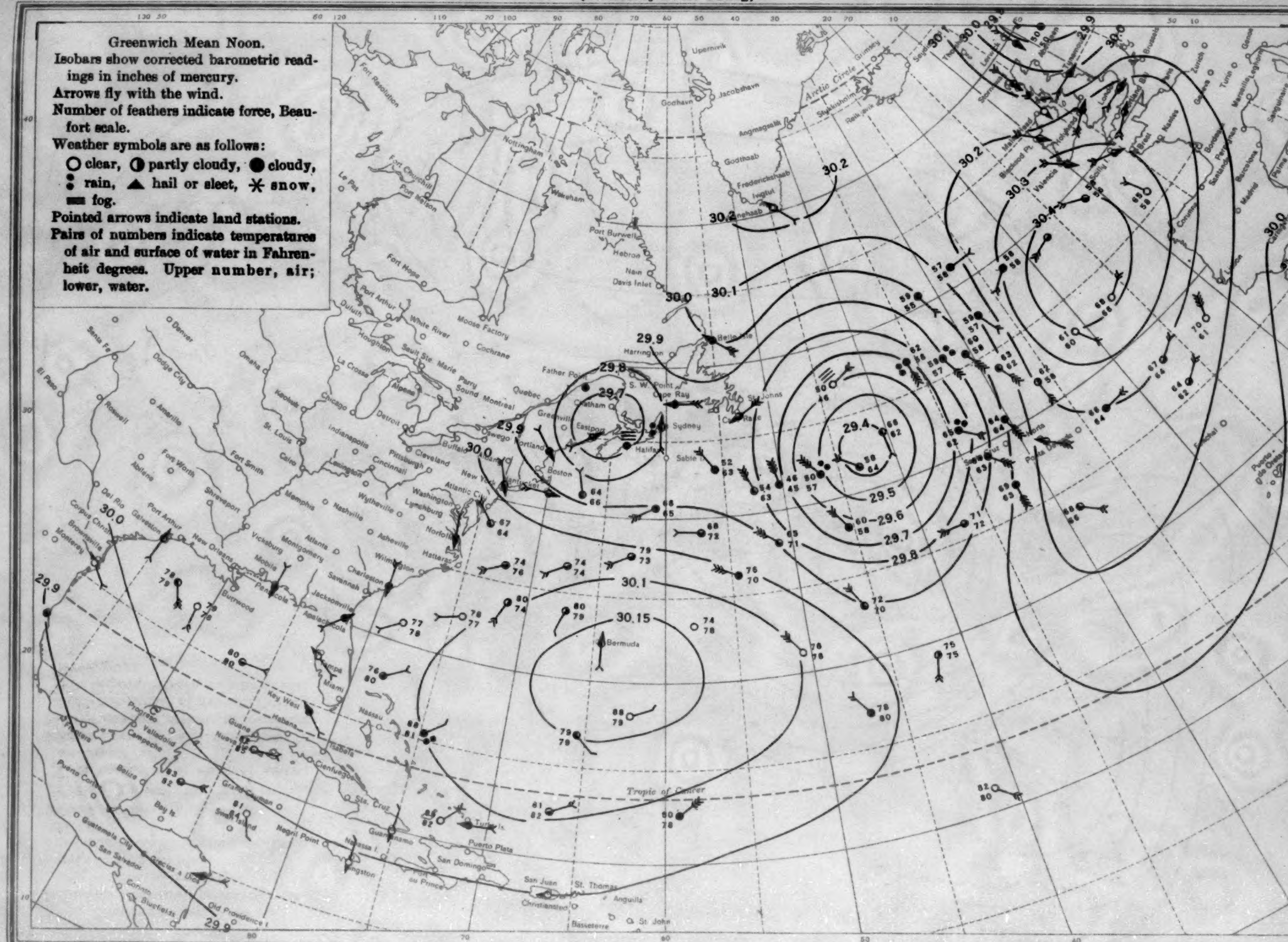


**Chart VIII. Weather Map of North Atlantic Ocean, June 15, 1928**
(Plotted by F. A. Young)



## Chart IX. Weather Map of North Atlantic Ocean, June 16, 1928
(Plotted by F. A. Young)

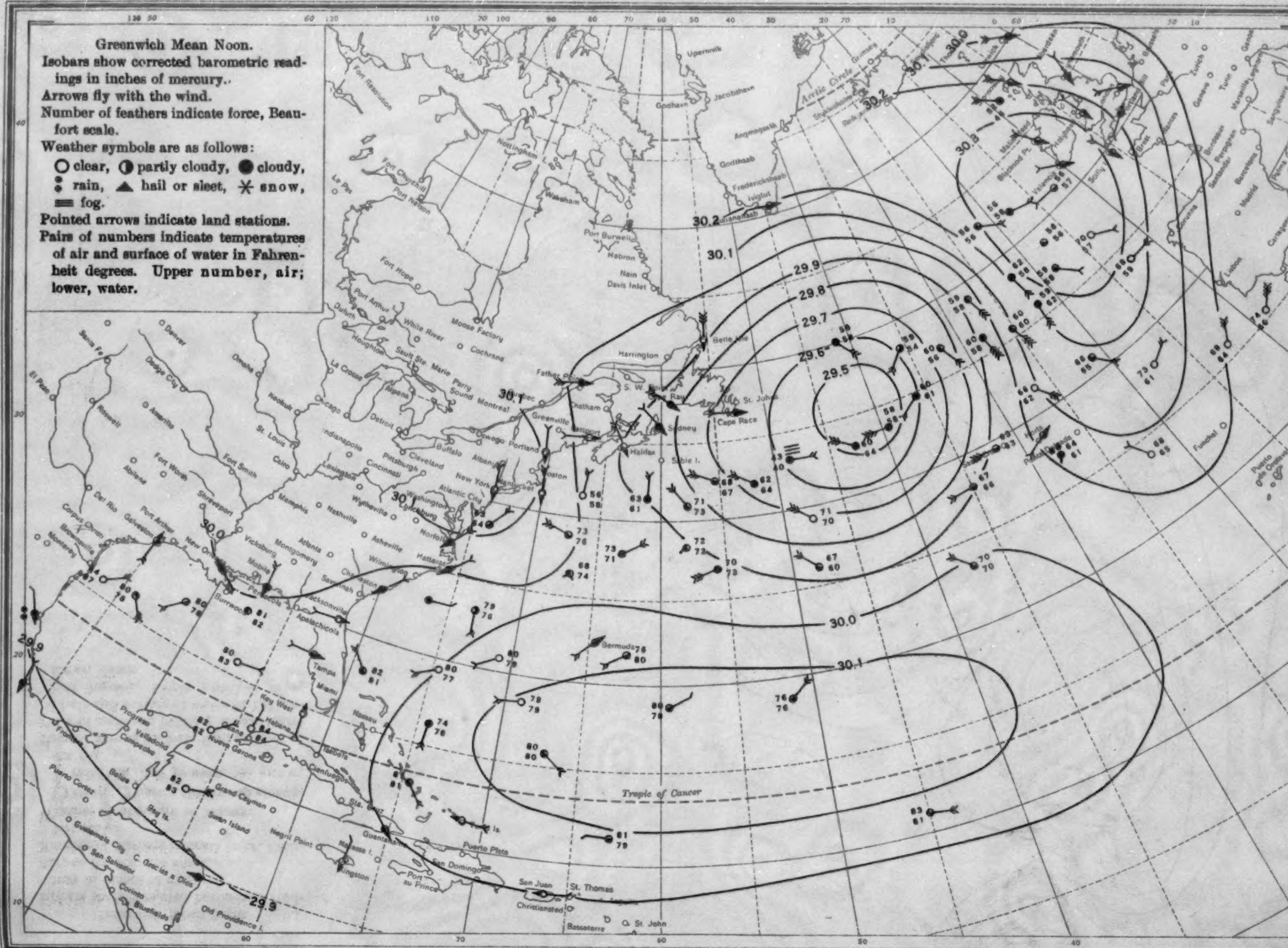
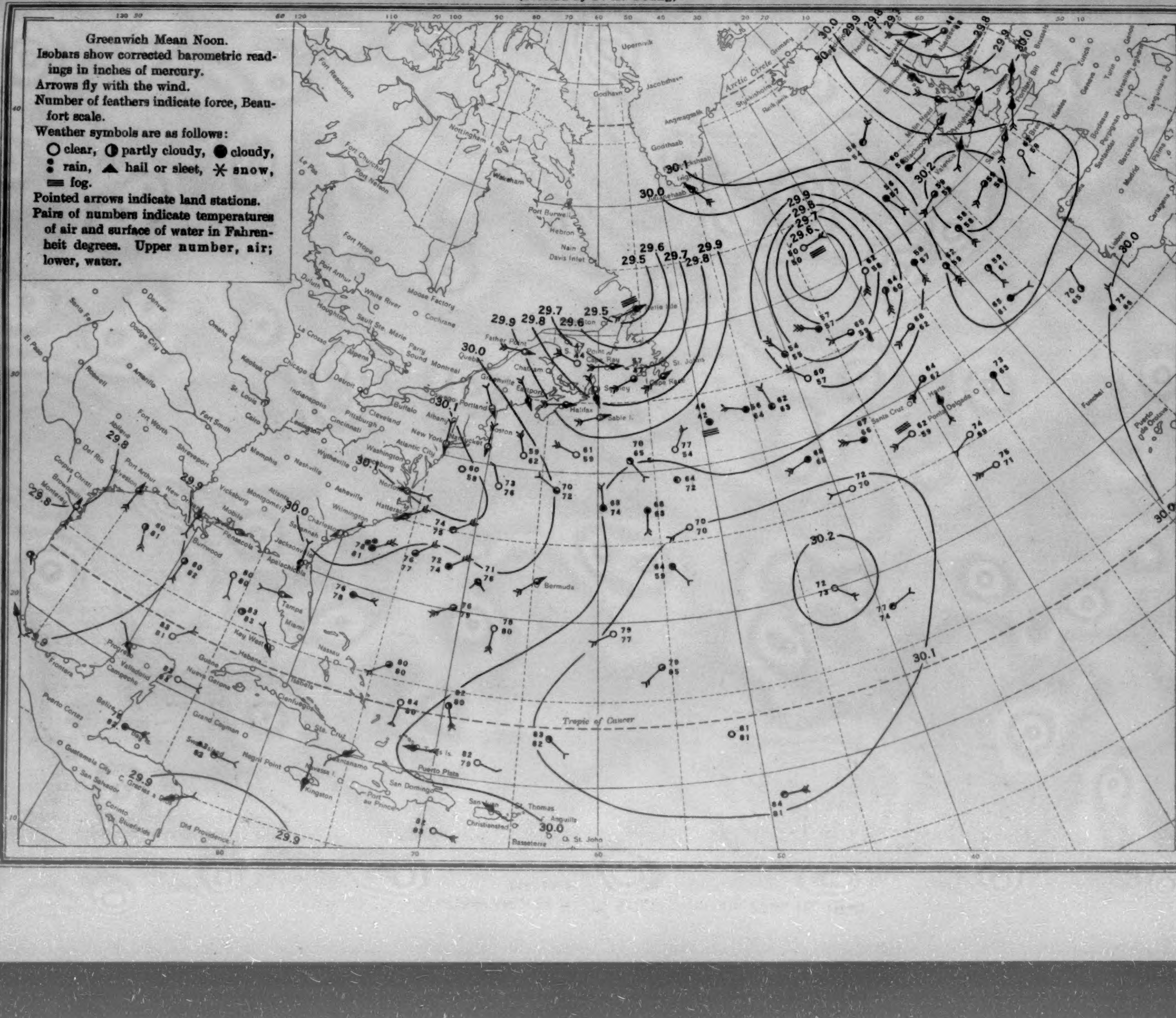



Chart X. Weather Map of North Atlantic Ocean, June 17, 1928
(Plotted by F. A. Young)

Chart X. Weather Map of North Atlantic Ocean, June 17, 1928
(Plotted by F. A. Young)



# Chart XI. Weather Map of North Atlantic Ocean, June 18, 1928

(Plotted by F. A. Young)